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Cost Estimations for Emission Control Related Components Systems and Cost Methodology Description

Mechanical Technology, Inc, Latham, N Y

Prepared for

Environmental Protection Agency, Ann Arbor, Mich Mobile Source Pollution Control Program

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16. ABSTRACT

This report presents estimates of the retail price equivalent (RPE) or "sticker price" for a variety of automotive exhaust emission control related components/systems. The author began with a three-level assumption as to industry makeup (supplier, vehicle assembly, dealer) and used this standard approach along with assumptions as to production volume and the amounts of labor, overhead, tooling, administrative, and depreciation expenses and profit at the supplier level, tooling, research and development, and administrative expenses and profit at the vehicle assembly level, and labor, overhead, and profit at the dealer level to determine the RPE. Where little physical description of a component could be found, a "best guess" effort was made. A methodology description is also included. It should be noted that since a specific production volume was assumed in each case, the RPE estimates are valid only within some relevant range of production volumes.

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Mobile Source Air Pollution Control
Emission Control Technology Division
Ann Arbor, Michigan 48105

EPA-460/3-78-002

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by

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Modification No. 3
to
Contract No. 68-03-3505

EPA Project Officer: Randall H. Field

Prepared for

ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Mobile Source Air Pollution Control
Emission Control Technology Division
Ann Arbor, Michigan 48105

March 1978

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This report was furnished to the Environmental Protection Agency by Rath & Strong, Inc., Lexington, Massachusetts in fulfillment of Modification No. 3 to Contract No. 68-03-3505. The contents of this report are reporduced herein as received from Rath & Strong, Inc. The opinions, findings, and conclusions expressed are those of the author and not necessarily those of the Environmental Protection Agency. Mention of company or product names is not to be considered as an endorsement by the Environmental Protection Agency.

Publication No. EPA-460/3-78-002

PREFACE

This report consists of the development of a manufacturing cost data base of a group of emission systems and components as specified by the Environmental Protection Agency. The cost methodology is included for each system. The dollar amounts presented in this report are in terms of 1977 dollars.

Scope of Work

A. The contractor shall provide all of the necessary facilities, equipment, personnel, analysis, and reporting required to complete the following tasks in an efficient and effective manner.

B. Task 1 - Cost of Components/Systems

1. The contractor shall provide cost estimates for the emission control or emission control related components/systems listed in Attachment A for 4, 6, and 8-cylinder engines with further cost breakdowns of these components/systems where indicated on the attachment. These individual costs shall include but not be limited to the following: a) material costs; b) labor costs; c) overhead costs, including indirect labor, supplies, electricity, heating, plant and equipment repairs, supervision, plant and equipment depreciation, insurance; and d) appropriate markup rates or factors.

2. These costs shall reflect economies of scale, current material, labor, and overhead costs, appropriate manufacturing processes, and shall be ranged to reflect a 3-year or a 12-year writeoff of investment.

3. The Project Officer must approve the choice of production volume used in calculating the effect due to economy of scale.

C. Task 2 - Description of Methodology

1. The contractor shall provide a detailed description of the methodology used to determine the estimates in Task 1 above. Where possible, more than one method shall be used to increase the assurance of the estimates' accuracy.

Attachment A

Components/Systems to be Cost-Estimated

1. PCV valve
2. TCS (thermal control switch)
3. OSAC (orifice spark advance control)
4. Deceleration valve
5. Anti-dieseling solenoid
6. Air injection system (breakdown by: pump, dump, lines, exh. man. mods.)
7. Air switching system (breakdown by: approx. 3 foot of tubing, 2-way valve)
8. Reed valve air system
9. EGR system (types: sonic-electronic with and without cooler, sonic-pneumatic with and without cooler, back-pressure modulated, venturi vac amplified)
10. Pelleted oxidation catalyst (as a function of volume, noble metal loading, and composition)
11. Monolithic oxidation catalyst (as a function of volume, noble metal loading, and composition)
12. Pelleted reduction catalyst (as a function of volume, noble metal loading, and composition)
13. Monolithic reduction catalyst (as a function of volume, noble metal loading, and composition)
14. Monolithic start catalyst (as a function of volume, noble metal loading, and composition)
15. Monolithic 3-way catalyst (as a function of volume, noble metal loading, and composition)
16. Metallic reduction catalyst (as a function of volume, noble metal loading, and composition)
17. Oxygen sensor (as a function of Pt loading)
18. Electronic fuel metering system (breakdown by: actuators, regulator, filters, tubing, pump, nozzles (# of cylinders plus one), vol air flow sensor (L-Jetronic and K-Jetronic type), mass air flow sensor (Chrysler type)

19. Thermal reactor (types: insulated with core, insulated without core)

20. Exhaust manifold (stock)

21. Port liners (types: cast in, inserted air-gap with and without locater ribs)

22. Radiator (types: stock, with 20% weight reduction)

23. Quick heat manifold (breakdown by: EFE valve with vacuum motor actuation and with 25 in^2 wavy steel heat transfer surface replacing 25 in^2 of cast iron)

24. Super early fuel evaporation (breakdown by: 2 valves, heat transfer surface, tubing)

25. Electric heated choke

26. High energy ignition

27. Breaker point ignition (breakdown by: centrifugal advance system, vacuum advance system)

28. Improved exhaust system (cost per foot of stainless steel from exhaust manifold to catalyst)

29. Standard steel exhaust system (cost per foot of low carbon steel from exhaust manifold to approximate catalyst location)

30. Insulated exhaust pipe (cost per foot of double wall stainless steel)

31. Carburetor modifications for altitude compensation (breakdown by: aneroid, linkage)

32. Carburetor modifications for feedback control unit (1, 2, 4 barrels)

33. Standard Carb (1, 2, 4 barrels)

34. Electronic control unit (with sensor inputs for controlling modulated AIR, modulated EGR, modulated A/F, modulated spark advance)

35. Air modulation system (with vacuum control)

36. Spark knock sensor (with piezo-electric accelerometer or pickup)

37. Transducers + Sensors (types: H_2O temperature, inlet air temperature, throttle-position, engine speed, engine load, fuel flow, transmission gear, EGR pintol position, crank angle, humidity)

Acknowledgements

This report has been generated from as much engineering data available at this writing. Some of the data is based on industrial engineering judgment. The cost data is based on the best possible industrial engineering estimating procedures using product knowledge, manufacturing experience, and learning curve techniques. Whenever possible other estimating work was used for comparative purposes. Also, the aftermarket selling price data was used to establish a frame of reference or an order of magnitude cost computation using known discount data.

The author would like to acknowledge the cooperation of EPA personnel Messrs. K. Hellman and R. Field. Mr. W. Leitch and Ms. S. Zemann of Rath & Strong were major contributors to this report. The production office of Rath & Strong typed and edited the final report to a level of detail beyond the original plan of work.

Introduction

In its regulation of the automobile industry, the U. S. Environmental Protection Agency is frequently confronted with the issue of cost to the consumer of systems installed on automobiles for the purpose of controlling emissions. Ideally, it would be desirable to determine the economic impact on the consumer for any emission standard proposed and on any vehicle for which such a standard would be applicable. Since such a task would involve a very high level of effort, a more realistic goal would be to determine an aggregate cost estimate representative of the cost of all components or systems of a similar nature, for example, EGR valves or EGR systems. This would necessarily imply that many individual components or systems could be expected to cost more or less than the aggregate or weighted average cost estimate.

In most situations a full cost, as opposed to a differential cost approach is more appropriate for determining the true cost of producing a particular component. This means that all components comprised by an automobile must reflect a share of fixed overhead and corporate level costs such as salaries, maintenance, insurance, heat, power, lighting, and so on. This approach is consistent with changes made to a vehicle which are expected to be of a relatively long-term nature whereas the differential cost approach of merely reflecting the addition of direct material, direct labor, and variable overhead costs due to an added component is adequate only for relatively short-term purposes.

Taking into account all of the variations in industry makeup which exist in the real world would present a very complex problem. For example, the number of suppliers supplying a corporation with a given component varies not only among the different components on a given vehicle but among the different vehicle manufacturers as well. Some suppliers are in turn supplied by other suppliers. Some suppliers supply components to more than one manufacturer. These variations influence production volume which in turn influences the economies of scale attainable by a manufacturer.

To make the problem more manageable, assumptions have been made which help simplify the cost estimate task. Figure 1, below, depicts the industrial makeup assumed in this study.

Judicious choice of production volumes helps minimize cost differences due to the reliance upon more than one supplier. (Automobile manufacturers are sometimes supplied a given component by more than one supplier as a precaution against labor strikes or other occurrences which might interrupt that supply.)

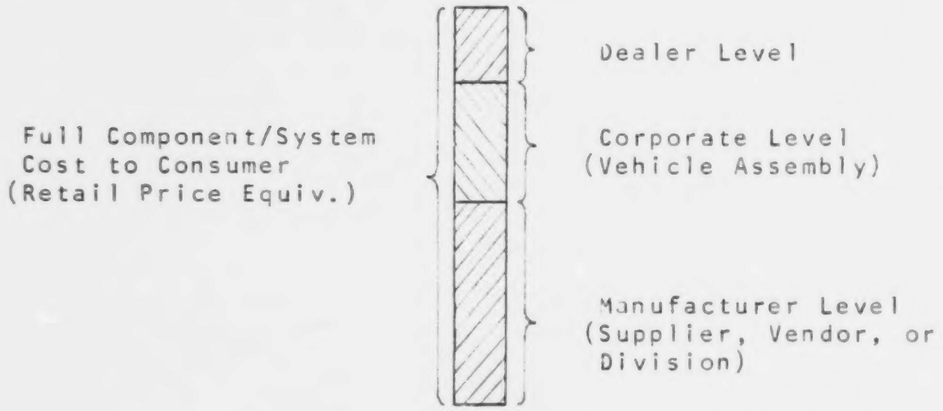
Dealer Level
Full Component/System Cost to Consumer (Retail Price Equiv.)
Corporate Level (Vehicle Assembly)
Manufacturer Level (Supplier, Vendor, or Division)

Figure 1 - 3-Level Industrial Makeup

It should also be noted that supplier (or vendor) and division can be used synonymously since the cost to the corporate level will be the same even though the division is a part of the corporation. This is because the division is managed as a profit center, that is, the corporation has placed the division in competition with other suppliers as a means of assuring a high level of efficiency. Therefore, the division's transfer price as it is called is the same as an independent supplier's price to the vehicle manufacturer.

With the three levels of industry making up the major elements of cost to the consumer, or, as used in this study, retail price equivalent, the basic formula is:

$$\text{Retail Price Equivalent} = \left\{\left[\text{Direct Material} + \text{Direct Labor} + \text{Fixed \& Variable Overhead}\right]\right.$$

$$\left.\times \left[1 + 0.2 \text{ for Corporate Allocation} + 0.2 \text{ for Supplier Profit}\right] + \text{Tooling Expense} + \text{Land \& Buildings Expense}\right\}$$

$$\times \left\{1 + 0.2 \text{ for Corporate Allocation} + 0.2 \text{ for Corporate Profit}\right.$$

$$\left. + 0.4 \text{ for Dealer Overhead \& Profit}\right\} + \text{Research \& Development} + \text{Tooling Expense}$$

Or, in abbreviated form:

$$RPE = \left\{\left[DM + DL + OH\right]\left[1.4\right] + TE + LBE\right\}\left\{1.8\right\} + RD + TE$$

Direct materials entail those materials of which a given component is comprised. Where possible actual weights of materials were used, but in some instances, estimates based on drawings and sketches were made necessary because of a lack of data. To determine the cost of materials, prices per unit weight as quoted in American Metal Market* were used plus 10%** to account for material waste and scrappage.

Direct labor includes the cost of laborers directly involved in the fabrication of a given component. It has been determined by using standard industrial engineering data and procedures.

Overhead includes both the fixed and variable components of overhead. The fixed portion includes supervisory salaries, building maintenance, heat, power, lighting, and other costs which are substantially unaffected by production volume while the variable portion includes small expendable tools, devices, and materials used in production, repairs and maintenance made to machines directly involved, and other overhead costs which tend to vary with production volume. A straight 40% of the direct labor amount is used to determine all overhead costs.

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* Metal Working News Edition

** Two exceptions are noteworthy: 1) exhaust systems assume approximately 35% scrappage, and 2) noble metals used in catalysts assume no waste or scrappage.

A figure of 20% applied to the sum of material, labor, and overhead costs is used to determine corporate allocation, in other words, the amount needed to cover the supplier's support from its front office. Also to the sum of material, labor, and overhead costs, a figure of 20% is applied to determine the supplier's profit, approximately half of which is used to pay corporate taxes with the remaining portion being divided between dividend disbursements to stockholders and retained earnings, which are used to finance working capital requirements (increases in current assets and/or decreases in current liabilities) and/or new capital expenditures (long-term assets).

Tooling expense consists of four components: one year recurring tooling expenses (tool bits, disposable jigs and fixtures, etc.); three year non-recurring tooling expenses (dies, etc.); twelve year machinery and equipment expenses; and twelve year launching costs (machinery foundations and other incidental set-up costs) which have been assumed to be 10% of the cost of machinery and equipment.

The construction of new production facilities has been assumed in some cases and their cost is amortized over 40 years. In most instances, however, space in existing facilities was assumed to have been made available for production purposes and, hence, is covered in the overhead costs.

The sum of the above costs, that is, material, labor, plant overhead, tooling expense, corporate allocation, and profit, makes up the price (or, in the case of a division, transfer price) which the supplier charges the vehicle manufacturer for a given component. At the vehicle assembly level, 20% of this price is charged or allocated for the vehicle manufacturer's corporate level support and 20% for corporate profit. To this is added research and development costs. (R & D may not wholly reflect all vehicle certification costs.) Also, a figure of 40% is applied to the supplier price to account for the dealer's margin which includes sales commissions, overhead, and profit.

Because of the need, in many instances, to make modifications to the engine or body to incorporate a component and to assemble it into a vehicle, these have also been accounted for at the division level and transferred to the corporate level at vehicle assembly.

Production volume is a very important assumption since it dictates not only over what number of units costs will be amortized or spread but also on what scale production will take place, in other words, the types and costs of machinery and equipment that will be involved. For this reason, the retail price equivalent estimates determined in this study are meaningless unless they are qualified with their associated production volume and are accurate only within some relevent range of volumes around that production volume.

In some instances, more than one production volume is assumed for the various individual parts making up a given component or system. This results from the assumption of necessary economies of scale for these parts where the vehicle manufacturer is not the only customer for whom they are produced. For example, hoses are frequently produced at higher unit volumes in order to satisfy more than just a single customer or market.

By discounting aftermarket selling prices, when available, by between 1/4 to 1/5, bracketing of the supplier's price had been expected to serve as a check against these estimates. However, because of differences between the assumptions inherent in this study and in actual production, variations may exist. It is assumed that these differences result from a given component either being of a somewhat proprietary nature and hence priced higher than assumed here (possibly, at what the market will bear) or are a result of subtle changes, for whatever reason, which do not allow full maximization of available economies of scale or a combination of the above two reasons.

All of the RPE estimates contained herein are by definition subject to some error. Where little physical description was available, a "best guess" effort was made and naturally these estimates are subject to more error. But, in general, those shown in greater detail are expected to be somewhat more accurate. To those critics who have significant disagreements with these estimates, it can be assumed that either their production assumptions are not at these assumed economies of scale or else they vary with respect to other specific assumptions made in this study regarding tooling costs, amortization schedules, profit level, etc., however, it is expected that a number of vehicle manufacturers may be below these estimates and a similar number above.

COST ESTIMATES

1.0 PCV Valve System

All engines produce small amounts of blowby gases, which seep past the piston rings, and into the crankcase. These blowby gases are the result of the high pressures developed within the combustion chamber, during the combustion process, and contain undesirable pollutants. To prevent blowby gases from entering the atmosphere, while allowing proper crankcase ventilation, all engines use a PCV system.

The PCV system prevents blowby gases from escaping by routing them through a vacuum controlled ventilating valve, and a hose, into the intake manifold. The blowby gases mix with the air/fuel mixture and are burned in the combustion chambers. When the engine is running, fresh air is drawn into the crankcase through a tube or hose connected to the air cleaner housing.

The PCV valve consists of a needle valve, spring and housing. When the engine is off, the spring holds the needle valve closed to stop vapors from entering the intake manifold. When the engine is running, manifold vacuum unseats the valve allowing crankcase vapors to enter the intake manifold. In case of a backfire (in the intake manifold) the valve closes, stopping the backflow and preventing ignition of fumes in the crankcase. During certain engine conditions, more blowby gases are created than the ventilator valve can handle. The excess is returned, through the air intake tube, into the air cleaner and carburetor, where it is disbursed in the air/fuel mixture, and, combusted within the engine.

1.10 PCV Valve System

BILL OF MATERIAL

Description	Material	Weight	Mat Costs	Labor Overhead	Mfg Costs	Reference*
PCV Valve		.074	-	.042	.042	6487935
Housing	Steel	.054	.011	.056	.067	
Spring	Spring Steel	.01	.002	.014	.016	
Needle	Steel	.014	.003	.028	.031	
			.016	.140	.156	
Pipe	Steel	.200	.060	.020	.080	0413449
Grommets	Rubber	.020	.004	.005	.009	3989344
Grommets ** (VC to AC)	Rubber	.040	.008	.010	.018	0412325
Total Parts			.072	.035	.107	
Vehicle Assembly		-	-	.126	.126	
Valve		-	-	.063		
Pipe		-	-	.063		
Engine Modification	-0-	-0-	-0-	.014	.014	
Total Manufacturing Costs at Plant Level					.403	

*Oldsmobile Reference Numbers

** VC = Valve Cover

AC = Air Cleaner

1.1 PCV Valve System

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			.016	.140	.156	
Pipe	Steel	.200	.060	.020	.080	0413449
Grommets	Rubber	.020	.004	.005	.009	3989344
Grommets (VC to AC)	Rubber	.040	.008	.010	.018	0412325
Total Parts					.107	
Vehicle Assembly		-	-	.126	.126	
Valve		-	-	.063		
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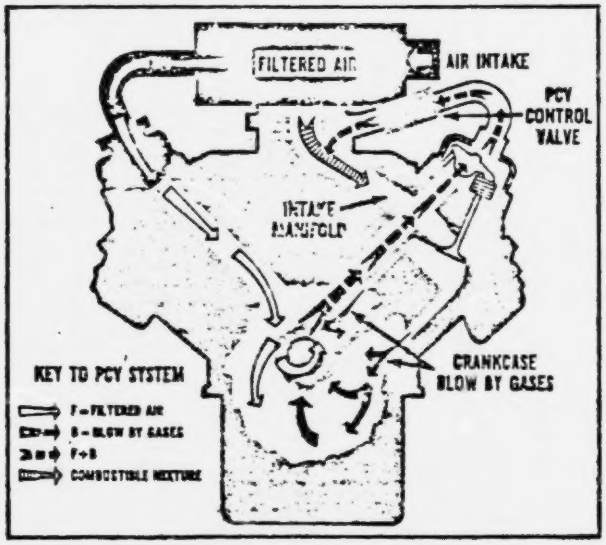
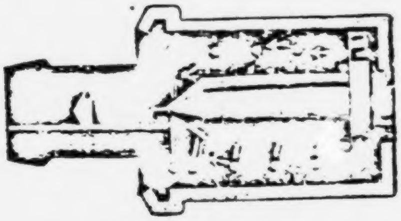
*Oldsmobile Reference Numbers


FILTERED AIR
AIR INTAKE
PCV CONTROL VALVE
INTAKE MANIFOLD
CRANKCASE BLOW BY GASES
KEY TO PCV SYSTEM
F—FILTERED AIR
B—BLOW BY GASES
F+B
COMBUSTIBLE MIXTURE

Typical PCV system



Typical PCV valve crossection

1.20 PCV Valve System--Tooling Costs--Amortized Per Piece

	Economic Volume Per Year	1 Year Recurring Tooling	3 Year Non-Recurring Tooling	12 Year Machinery Equipment	4 Year Launching Costs	40 Year Land & Buildings	Amortization Per Piece
Valve Assembly							
Housing		.050	.017	.020	.006		.093
Amortized	1,000,000	50,000	50,000	250,000	25,000	-	
Spring		.002	.002	.003	-		.007
Amortized	3,000,000	5,000	15,000	100,000	5,000	-	
Needle		.005	.002	.002	-		.009
Amortized	2,000,000	10,000	12,000	50,000	5,000	-	
		.057	.021	.025	.006 Valve		.109
Pipe		.005	.001	.001	-		.007
Amortized	2,000,000	10,000	5,000	25,000	2,000	-	
Grommets		.004	.002	.002	-		.008
Amortized	4,000,000	15,000	20,000	100,000	5,000	-	
Grommets		.004	.002	.002	-		.008
Amortized	4,000,000	15,000	20,000	100,000	5,000	-	
Total		.013	.005	.005	-		.023
Vehicle Assembly		.001	.001	.0003			.0023
Amortized	300,000	3,000	5,000	10,000	2,000	-	
Engine Modification		.002	.001	.0015	-		.0045
Amortized	300,000	6,000	12,000	60,000	5,000	-	
Total--Tooling/Piece		.003	.002	.0018	-		.1388

Research and Development by Vehicle Manufacturing: $100,000 for 2 Years.

Using a 3-year amortizing rule, the R/D per piece = $.022.

1.30 PCV Valve System

TOTAL MANUFACTURING COSTS

Part	Mat	Labor	Plant Over-Head 1.40	Plant Mfg Costs	Tooling		.20 MC Corp Costs	.20 MC Corp Profit	Vendor Corp Selling Price
					Exp.	Inv.			
PCV Valve	.016	.100	.40	.156	.078	.031	.030	.030	.325
Pipe	.060	.0143	.0057	.080	.006	.001	.016	.016	.119
Grommets	.012	.0107	.004	.0267	.012	.004	.006	.006	.055

1.40 PCV Valve System

RETAIL PRICE EQUIVALENT
AT THE VEHICLE LEVEL

Part	Plant or Vendor Selling Price	R&D	Invest Tools & Equip	Corp Allocation .20vc	Corp Profit .20vc	.40sp Dealer Markup	Vehicle Retail Price Equivalent
PCV Valve	.325	.022	-0-	.0652	.0652	.1304	.608
Pipe	.119	-0-	-0-	.0238	.0238	.0576	.224
Grommets	.055	-0-	-0-	.011	.011	.022	.099
Vehicle Assembly	.126	-0-	.0023	.013	.013	.026	.180
Engine Mod	.014	-0-	.0045	.003	.003	.006	.031
Total PCV System Retail Price Equivalent							1.142

1.50 PCV Valve System

Cost Comparison to Aftermarket Selling Prices

Using the aftermarket discount data in the references, we can conclude that the vendor selling price is about 1/4 to 1/5 of the aftermarket selling price. This rule is applicable if the part requires a minimum of packaging and handling costs, in relation to the value of the part and if the production volumes are within close agreement.

Using the following aftermarket prices for the PCV valve:

	Chilton	Sears
	3.12	1.76
Vendor Cost 1/4	.78	.44
Vendor Cost 1/5	.62	.35

The estimated vendor cost is $.326 for the PCV valve. This Chilton price is the cost to the customer at the service station.

1.60 PCV Valve System

Cost Methodology

The weight data for the components was obtained from an Oldsmobile parts computer document. The material costs are computed by using the 1977 mill prices, obtained from Metalworking News' metals market data. The labor costs are estimates of production, using today's technology, with a relatively high level of automation. The overhead and corporate cost data was obtained from a U.S.A. company.

The tooling costs are estimates of expendable tooling, i.e., jigs, fixtures, molds, or dies; and machinery or equipment, launching costs, to put the product into production at the plant level.

Judgment was used in assessing whether land or building investments were required to put this product into production and it was concluded that they were not.

The engine was modified to accept the valve and the piping, so, these costs are considered as part of the total cost.

The vehicle assembly required the addition of labor to install the valve and the piping.

1.70 Applications of PCV Valve systems to vehicle and engine configurations, regarding 4, 6, and 8 cylinder models, was assumed to be equivalent.

2.0 TCS Thermal Control Switch System--Thermal Vacuum Switch System

THERMOSTATIC VACUUM SWITCH

Description of Switch

The Thermostatic Vacuum Switch is not an emission control device; but, it is so closely connected with the emission controls that a description of how it works is necessary.

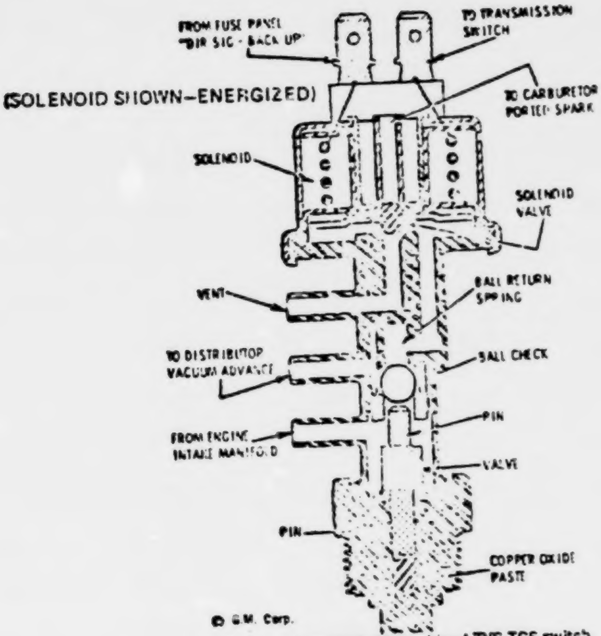
The thermostatic vacuum switch is located at the front of the intake manifold and is screwed into the water passage. Its purpose is to help control overheating. Whenever the engine coolant temperature rises to about 230°F or more, the thermostatic vacuum switch changes the distributor vacuum advance from ported vacuum to manifold vacuum, which advances the spark, speeds up the engine pulling more air through the radiator and forcing greater coolant flow which helps cool the engine. When the engine returns to normal temperature, the distributor is switched back to ported vacuum.

Following are the temperatures at which the change is made from ported to manifold vacuum, as listed by Oldsmobile:

1966-67	230° F
1968	220° F
1969-70	223° F
1971-72	218-224° F
1973-74	226° F

Due to manufacturing tolerances, all the 1968-73-74 thermostatic vacuum switches can be considered identical in operation, even though the thread size and vacuum ports may be different.

2.0 TCS/TVS Switch


FROM FUSE PANEL "DIR SIG - BACK UP"
TO TRANSMISSION SWITCH
(SOLENOID SHOWN—ENERGIZED)
TO CARBURETOR PORTED SPARK
SOLENOID
SOLENOID VALVE
VENT
BALL RETURN SPRING
TO DISTRIBUTOR VACUUM ADVANCE
BALL CHECK
PIN
FROM ENGINE INTAKE MANIFOLD
VALVE
PIN
COPPER OXIDE PASTE

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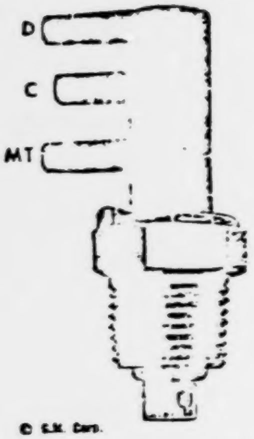
Cutaway of the 1971-72 combined TVS-TCS switch



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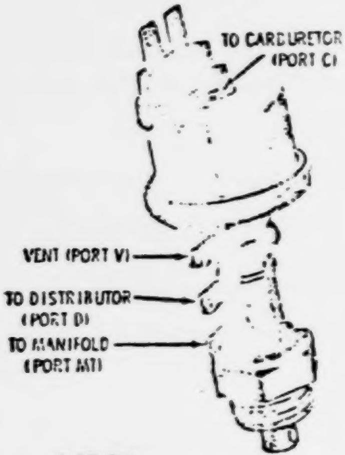
1968 Oldsmobile thermostatic vacuum switch


TO CARBURETOR (PORT C)
VENT (PORT V)
TO DISTRIBUTOR (PORT D)
TO MANIFOLD (PORT MT)

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In 1971 and 72 the TVS was combined with the TCS solenoid

2.1 Thermal Vacuum Switch System--TVS/TCS

BILL OF MATERIAL

	Material	Weight	Material Costs	Labor	Labor Overhead	Mfg Costs	Reference
TVS Valve	Assembly	.216	-	.075	.030	.1050	00413473
Prong Plug	CW	.0108	.0022	.025	.010	.0372	
Solenoid	Steel	.0560	.0112	.012	.005	.0282	
Solenoid Valve	Steel	.0108	.0022	.006	.002	.0102	
Vent Body	Steel	.0560	.0112	.025	.010	.0462	
Ball & Seat	PM Steel	.0108	.0022	.006	.002	.0102	
Screw Plug	Steel	.0560	.0112	.006	.002	.0192	
Pin & Valve	Steel	.0108	.0022	.006	.002	.0102	
CuO Paste	CuO	.0054	.0010	.001	.0004	.0024	
			.0434	.162	.0634	.2688	
Hoses WP/Rad	Rubber	.030	.006	.006	.002	.0140	
Hose Clamps	Steel	.010	.002	.006	.002	.0100	
Hose to Distr.	Rubber	.013	.003	.006	.002	.0110	
Hose to B-Valve	Rubber	.015	.005	.006	.002	.0130	
Hose to Carb	Rubber	.115	.023	.012	.005	.0400	550548
			.039	.036	.013	.0880	

System Total Parts			
Vehicle Assembly	.075	.030	.1050
Engine Modification	.025	.010	.0350
Total Parts and Vehicle			.4968

2.2 Thermal Vacuum Switch System. TVS/TCS--Tooling Costs--Amortization Per Part

Part	Economic Volume	1 Year Recurring Tooling	3 Year Non-Recurring Tooling	12 Year Mach & Equipment	12 Year Launching Costs	40 Year Land & Building	Amortization Total Per Piece
		.0100	.0170	.0080	.0020	-	.0370
Valve Assem	1,000,000	10,000	50,000	100,000	20,000		
		.0025	.0008	.0001	.0001	-	.0035
Prong Plug	2,000,000	5,000	5,000	15,000	5,000		
		.0100	.0050	.0020	.0002	-	.0172
Solenoid	2,000,000	20,000	30,000	50,000	5,000		
		.0010	.0007	.0005	.0001	-	.0023
Solenoid Vlv	4,000,000	5,000	10,000	25,000	10,000		
		.0250	.0170	.0130	.0020	-	.0570
Vent Body	1,000,000	25,000	50,000	150,000	20,000		
		.0012	.0008	.0020	.0002	-	.0042
Ball & Seat	4,000,000	5,000	10,000	55,000	5,000		
		.0024	.0024	.0022	.0002	-	.0072
Screw Plug	2,000,000	5,000	15,000	50,000	5,000		
		.0012	.0008	.0008	.0001	-	.0029
Pin & Valve	4,000,000	5,000	10,000	20,000	2,000		
		.0533	.0445	.0286	.0049		.1313
		.004	.0010	.0030	.0003		.0083
Hoses	5,000,000	20,000	25,000	150,000	15,000		
		.002	.0010	.0008	.0001		.0039
Clamps	5,000,000	10,000	25,000	50,000	5,000		
		.006	.002	.0038	.0004		.0122
		.0167	.0333	.0056	.0006		.0552
Vehicle Assem	300,000	5,000	30,000	20,000	2,000		
		.0333	.0222	.0139	.0014		.0708
Engine Mod	300,000	10,000	20,000	50,000	5,000		
							.1209
						Total	.2705

Research and Development: $300,000 for 2 years

2.40 TVS/TCS Thermal Vacuum Switch System

RETAIL PRICE EQUIVALENT
AT THE VEHICLE LEVEL

Part	Plant Vendor S.P.	R&D	Tools and Equip	Corp Allocation 20%of S.P.	Corp Profit 20%of S.P.	Dealer Markup 40%	Vehicle Retail Price Equiv
TVS/TCS	.5077	,300	-0-	.1015	.1015	.2031	1.2138
Hoses & Clamps	.1370	-0-	-0-	.0274	.0274	.0543	.2466
Vehicle	.105	-0-	.0562	.021	.021	.042	.2452
Engine Mod	.035	-0-	.0708	.007	.007	.014	.1338

Total TCS/TVS System
Retail Price Equivalent 1.8394

2.30 TVS Thermal Vacuum Control Switch

TOTAL MANUFACTURING COSTS

Part	Mat	Labor	Plant Overhead 0.40	Plant Mfg Costs	Tooling		.2 x MC Corp	Corp Profit .2 x MC	Vendor
					Exp	Inv			
TVS Valve	.0434	.162	.0634	.2688	.0978	.0335	.0538	.0538	.5077
Hoses & Clamps	.039	.036	.013	.0880	.008	.0042	.0184	.0184	.1370

2.50 TVS - Valve System--Cost Comparison to Aftermarket Selling Prices

Using the aftermarket discount data, the aftermarket selling price for the TVS valve is:

	Chilton	Reference	
1970/74 TVS	9.80	00413473	Oldsmobile
1/4 Ratio SP/MC	2.45		
1/5 Ratio	1.96		
1973/77 TVS	5.38	6490440	Pontiac
1/4 Ratio	1.34		
1/5 Ratio	1.08		

The estimated vendor costs are $ .5077

The retail price equivalent for the valve on the vehicle is $ 1.214.

2.60 TCS/TVS Valve System--Cost Methodology

The weight data was obtained from an Oldsmobile parts list. The material costs are computed using the 1977 mill prices obtained from AMM-News.

The labor costs are estimates of production costs, using today's technology, with a relatively high level of automation. The overhead costs and corporate costs data were obtained from an automobile company.

The tooling costs are estimates of expendable cutting tools and dies, jigs, fixtures, molds or dies, machinery or equipment, and launching costs.

Judgment was used in assessing whether new land or buildings were needed to produce this valve system in the United States and it was concluded they were not.

The vehicle assembly changes and engine modifications were included in the costs of the system installation on a vehicle.

2.70 Application of the TVS Valve System on Various Engines

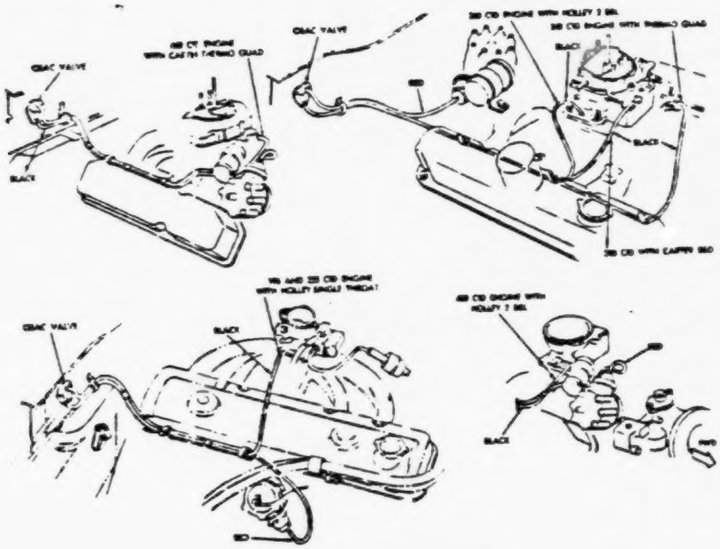
Considerable variation exists in the systems over the past seven years. We selected the General Motors system because of its universal application to the vehicles in their product line.

No significant difference existed in the TVS for 4, 6, or 8 cylinder engines.

3.0 Orifice Spark Advance Control (OSAC) System

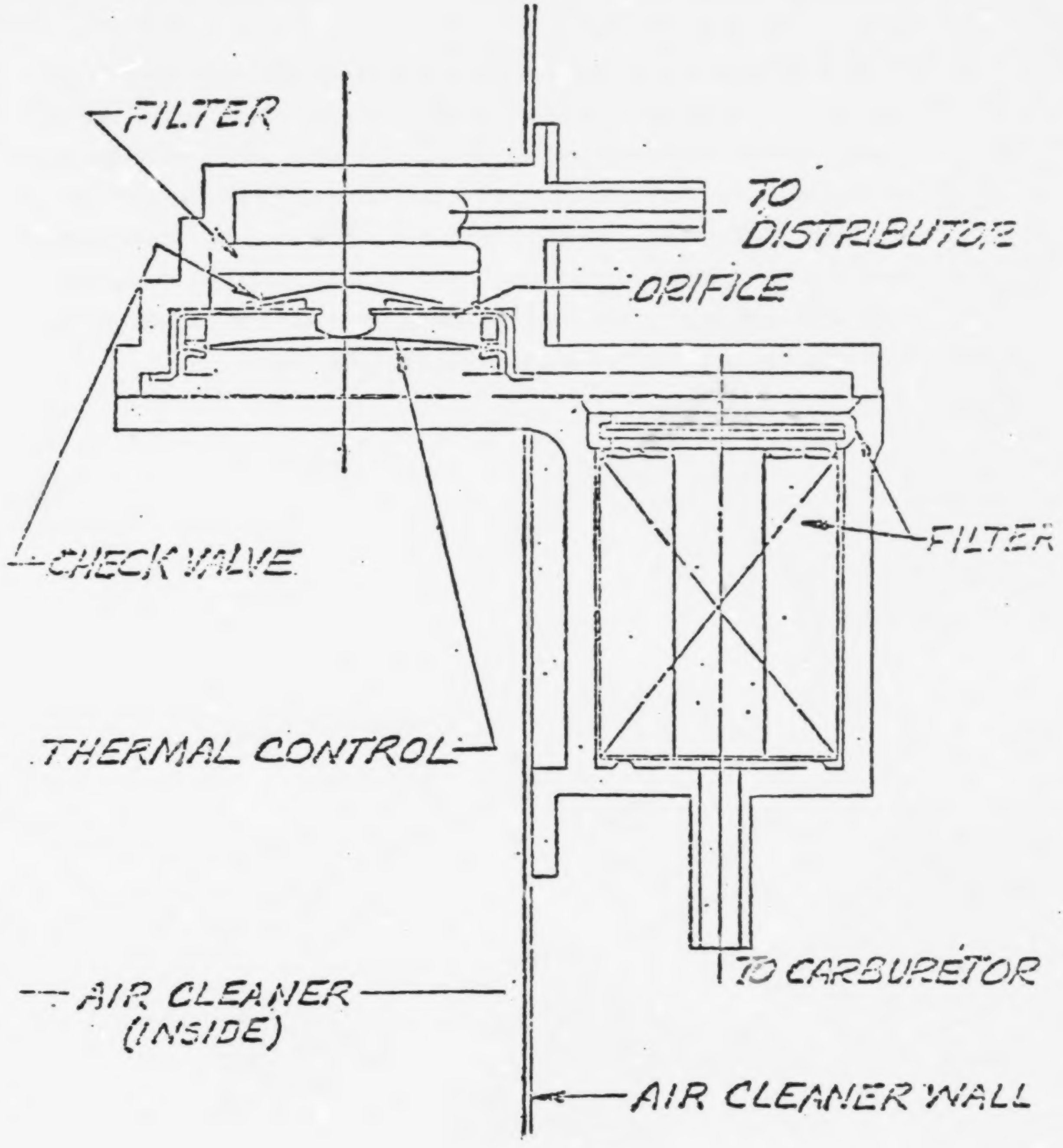
Description of System

Ported vacuum to the distributor is delayed by as much as 17 seconds, by an OSAC valve mounted on the firewall. The OSAC valve is a calibrated orifice, combined with a check valve and a temperature control. When the carburetor throttle opens to uncover the spark port, ported vacuum goes through the hose to the OSAC valve. The OSAC valve delays the application of the ported vacuum to the distributor diaphragm. When the throttle is closed, shutting off vacuum to the spark port, the OSAC check valve opens immediately to let out the vacuum between the OSAC valve and the distributor.



1973 OSAC valve vacuum hoses

OSAC CONTROL UNIT


FILTER
TO DISTRIBUTOR
ORIFICE
CHECK VALVE
FILTER
THERMAL CONTROL
TO CARBURETOR
AIR CLEANER (INSIDE)
AIR CLEANER WALL

3.1 OSAC Valve System

BILL OF MATERIAL

Part	Material	Weight	Matl Costs	Labor	Labor Overhead	Mfg Costs	Reference
OSAC Valve	Assem	.200	–	.0625	.0250	.0875	3755731
Housing	Alum	.050	.030	.0312	.0125	.0737	or
Orifice Filter	Plastic	.010	.007	.0156	.0062	.0288	3755582
Check Valve	Steel	.010	.002	.0156	.0062	.0238	
Thermal Control	Bimetal	.010	.010	.0078	.0031	.0209	
Orifice	Steel	.010	002	.0078	.0031	.0129	
Filter Housing	Steel	.050	.010	.0312	.0125	.0537	
Filter	Paper	.040	.012	.0625	.0250	.0995	
Total Valve			.073	.2342	.0936	.4008	
Hose Assembly	Rubber	.300	.060	.0312	.0125	.1037	3755733
Total OSAC System						.5045	
Vehicle Assembly			–	.1250	.0500	.1750	
Engine Mod			–	.0625	.0250	.0875	
Total Vehicle Installation						.7670	

3.2 OSAC Valve System--Tooling Costs--Amortization Per Part

Part	Economic Volume	1 Year Recurring Tooling	3 Year Non-Recurring Tooling	12 Year Machinery & Equip	12 Year Launching Costs	40 Year Land & Building	Amortization Total Per Piece
		.0100	.0100	.0040	.0004		.0244
OSAC Valve	1,000,000	10,000	30,000	50,000	5,000	-	
		.0100	.0100	.0050	.0005		.0255
Housing	2,000,000	20,000	60,000	120,000	12,000	-	
		.0012	.0050	.0005	.0001		.0068
Orifice Filter	4,000,000	5,000	60,000	24,000	2,400	-	
		.0025	.0025	.0010	.0001		.0061
Check Valve	4,000,000	10,000	30,000	48,000	4,800	-	
		.0050	.0050	.0010	.0001		.0111
Thermal Control	4,000,000	20,000	60,000	48,000	4,800	-	
		.0025	.0025	.0005	.0001		.0056
Orifice	4,000,000	10,000	30,000	24,000	2,400	-	
		.0100	.0160	.0050	.0005		.0315
Filter Housing	2,000,000	20,000	100,000	120,000	12,000	-	
		.0100	.0050	.0050	.0005		.0205
Filter	4,000,000	40,000	60,000	240,000	24,000	-	
		.0512	.0560	.0220	.0023		.1315
		.0040	.0016	.0026	.0003		.0085
Hose	5,000,000	20,000	25,000	150,000	15,000	-	
		.0167	.0333	.0056	.0006		.0562
Vehicle Assem	300,000	5,000	30,000	20,000	2,000	-	
		.0333	.0222	.0056	.0006		.0617
Engine Mod	300,000	10,000	20,000	20,000	2,000	-	
Total Systems on Vehicle							.2494

R&D Estimate: 150,000 for 2 years or, for 3 year payback, the engine piece is 0.15

3.3 OSAC Valve System

TOTAL MANUFACTURING COSTS

Part	Mat	Labor	Plant Overhead	Plant Mfg Costs	Tooling		.2 x MC Corp.	.2 x MC Corp Profit	Mfg. Vendor Costs
					Exp.	Inv.			
OSAC Valve	.073	.2342	.0936	.4008	.1072	.0243	.0802	.0802	.6927
Hose Assem	.060	.0312	.0125	.1037	.0056	.0029	.0207	.0207	.1536

3.4 OSAC Valve System

RETAIL PRICE EQUIVALENT
AT THE VEHICLE LEVEL

Part	Plant Vendor S.P.	R&D	Tools and Equip	20% of S.P. Corp Allocation	20% of S.P. Corp Profit	40% of S.P. Dealer Markup	Vehicle Retail Price Equiv
OSAC Valve	.6927	0.150	-0-	.1385	.1385	.2770	1.3967
Hose Assem	.1536	-0-0	-0-	.031	.031	.0614	.2770
Vehicle Assem	.1750	-	.0562	.035	.035	.0700	.3712
Engine	.0875	-	.0617	.017	.017	.0350	.2182
							1.9861

Total Vehicle
Retail Price Equivalent

3.50 OSAC Cost Comparison to Aftermarket Selling Prices

Using the aftermarket discount data and the aftermarket selling price, the following analysis is projected:

	Chilton	Reference
OSAC Valve	13.10	3755582
Disc 1/4	3.25	
Disc 1/5	2.62	

The estimated vendor costs are .6927. The retail price equivalent for the valve on the vehicle is 1.3967.

3.60 OSAC Valve System--Cost Methodology

The weight data was obtained from Chrysler's engineering data book. The material costs are compiled using the 1977 AMM mill prices.

The labor costs are estimates of production costs, using today's technology and the assumed economies of scale. The overhead data are from a company communication. The tooling costs are estimates of expendable tools, jigs, fixtures, and dies as well as estimates of equipment and machinery required to produce the components.

No new buildings were assumed necessary to produce these parts.

The vehicle assembly costs and the engine (air cleaner) charges were included in the costs, at the vehicle level.

3.70 OSAC Valve--Application of the Valve System

The only significant difference in the valve system installation, for various Chrysler engines, is in the lengths and number of hoses. See sketch in Section 3.0.

4.0 Deceleration Valve System

Description of Deceleration Valve - 1970

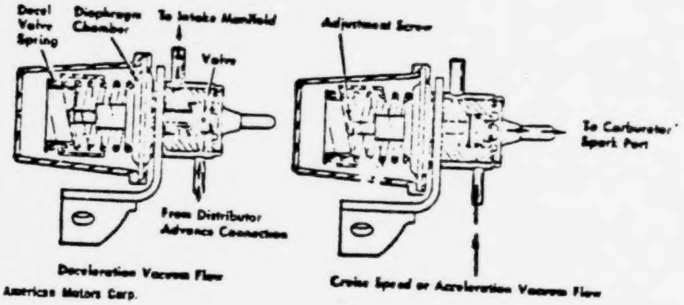
This is the same type of valve that was used for many years on Chrysler products. Any distributor vacuum unit, that uses ported vacuum spark control, goes to the neutral position when the throttle is closed. This is fine at idle, when spark advance is not wanted. But during closed throttle deceleration, there is also no spark advance; and, it was discovered that this has a detrimental effect on emissions. The deceleration valve corrects this by advancing the spark during deceleration.

4.0 Deceleration Valve

Description of Valve

This valve is used with dual diaphragm distributors to cancel the retard during deceleration, by sending manifold vacuum to the advance diaphragm. During deceleration, the vacuum advance stays at the fully advanced position.

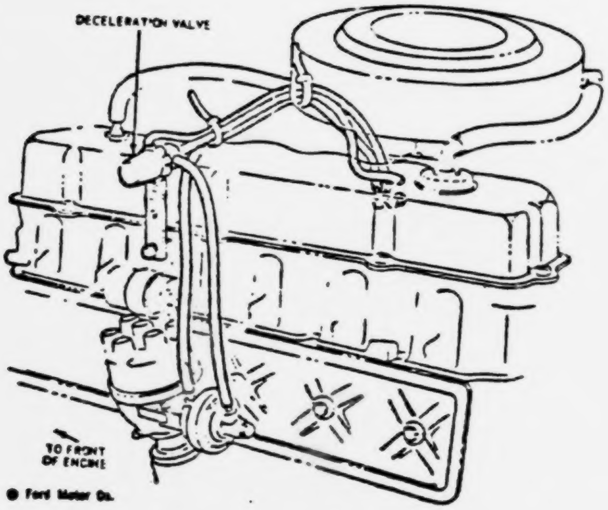
DECELERATION VALVE


Decel Valve Spring
Diaphragm Chamber
To Intake Manifold
Valve
From Distributor Advance Connection
Adjustment Screw
To Carburetor Spark Port
Deceleration Vacuum Flow
Cruise Speed or Acceleration Vacuum Flow

© American Motors Corp.

The spark valve was used only in 1970, and is similar to the valve used [illegible]sler products

DISTRIBUTOR VACUUM DECELERATION VALVE


DECELERATION VALVE
TO FRONT OF ENGINE

© Ford Motor Co.

Typical deceleration valve installations on 6 cylinder engines

4.1 Deceleration Valve System

BILL OF MATERIAL

Part	Material	Weight	Mat Cost	Labor	Labor Overhead	Mfg Cost	Reference
Decel Valve	Assem	.200	-	.0500	.0200	.0700	
Valve Housing	Steel	.025	.005	.0250	.0100	.0400	American Moto
Valve Seat	P Metal	.020	.008	.0125	.0050	.0255	Ford Motor Co
Valve Stem	Steel	.010	.002	.0125	.0050	.0195	Opel Manta
Mktg. Brkt.	Steel	.025	.005	.0125	.0050	.0225	9293056
Diaphragm	Steel	.025	.005	.0250	.0100	.0400	
Spring	Steel	.020	.004	.0125	.0050	.0215	
Spring Retainer	Steel	.020	.004	.0125	.0050	.0215	
Adj. Screw	Steel	.010	.002	.0060	.0024	.0104	
Spring Hsg.	Steel	.025	.005	.0250	.0100	.0400	
Total Valve			.040	.1935	.0774	.3109	
Hose Assem	Rubber	.300	.060	.0312	.0125	.1037	
Total Decel Sys.						.4146	
Vehicle Assy	-	-	-	.1250	.0500	.1750	
Engine Mod.				.0625	.0250	.0875	
Total Mfg. Cost						.6771	

4.2 Deceleration Valve System Tooling Costs--Amortization Per Piece

Part	Economic Volume	1 Year Recurring Tooling	3 Year Non-Recurring Tooling	12 Year Machine & Equipment	12 Year Launching Costs	40 Year Land & Building	Amortization Total Per Piece
		.0100	.0100	.0042	.0004	-	.0246
Decel Valve	1,000,000	10,000	30,000	50,000	5,000	-	
		.0025	.0033	.0062	.0006		.0126
Valve Housing	2,000,000	5,000	20,000	150,000	15,000	-	
		.0025	.0025	.0021	.0002		.0073
Valve Seat	4,000,000	10,000	30,000	100,000	10,000	-	
		.0012	.0017	.0010	.0001		.0040
Valve Stem	4,000,000	5,000	20,000	50,000	5,000	-	
		.0025	.0050	.0012	.0001		.0088
Mktg Brkt	2,000,000	5,000	30,000	30,000	3,000	-	
		.0100	.0083	.0042	.0004		.0229
Diaphragm	2,000,000	20,000	50,000	100,000	10,000	-	
		.0012	.0025	.0021	.0002		.0060
Spring	4,000,000	5,000	30,000	100,000	10,000	-	
		.0025	.0017	.0006	.0001		.0049
Spring Retainer	4,000,000	10,000	20,000	30,000	3,000	-	
		.0012	.0017	.0006	.0001		.0036
Adj. Screw	4,000,000	5,000	20,000	30,000	3,000	-	
		.0050	.0050	.0021	.0002		.0123
Spring Hsg.	2,000,000	10,000	30,000	50,000	5,000	-	
		.0386	.0417	.0243	.0024		.1070
		.0040	.0017	.0025	.0002		.0084
Hose Assem	5,000,000	20,000	25,000	150,000	15,000		
		.0167	.0333	.0056	.0006		.0561
Vehicle Assem	300,000	5,000	30,000	20,000	2,000		
		.0333	.0222	.0056	.0006		.0617
Engine Mod	300,000	10,000	20,000	20,000	2,000		
Total Vehicle							.2332

R & D estimate - 150,000 for 2 years or 0.15 per piece when amortized over 3 years.

4.3 Deceleration Valve

TOTAL MANUFACTURING COSTS

Part	Mat	Labor	Plant Overhead	Plant Mfg Costs	Tooling		.2 x MC Corp	.2 x MC Corp Profit	Mfg. Vendor Costs
					Exp.	Inv.			
Decel Valve	.040	.1935	.0774	.3109	.0803	.0267	.0622	.0622	.5423
Hose	.060	.0312	.0125	.1037	.0057	.0027	.0207	.0207	.1536

4.4 Deceleration Valve

RETAIL PRICE EQUIVALENT
AT THE VEHICLE LEVEL

Part	Plant Vendor Costs	R&D	Tools and Equip	Corp .2 MC Alloc	Corp .2 MC Profit	Dealer .4 MC Markup	Vehicle Retail Price Equiv
Decel Valve	.5423	0.150	-0-	.1085	.1085	.2169	1.1261
Hoses	.1536	-0-	-0-	.0307	.0307	.0614	.2765
Vehicle Assy	.1750	-	.0561	.0350	.0350	.0700	.3711
Engine	.0875	-	.0617	.0175	.0175	.0350	.2192
							1.9929

Total Vehicle
Retail Price Equivalent

4.50 Deceleration Valve--Cost Comparison to Aftermarket Selling Price

Using the aftermarket selling price and discount data, the following analysis is projected:

	Chilton	Reference
Deceleration Valve	12.15	9293056
Discount 1/4	3.04	
Discount 1/5	2.43	

The estimated vendor costs are .5423 .The retail price equivalent for the valve on the vehicle is 1.1261

4.60 Deceleration Valve--Cost Methodology

The weight data was estimated to be .300, based on a similar valve design in the Chrysler data base. The material costs were computed using 1977 AMM mill prices.

The labor costs are estimates of production costs using today's technology, and assumed economies of scale. The overhead data was obtained from a manufacturer of vehicles.

The tooling costs are estimates of expendable tools, jigs and fixtures, and dies, as well as estimates of equipment and machinery to produce the components.

The new buildings were assumed necessary to produce these parts.

The vehicle assembly costs and the engine changes were included at the vehicle level.

4.70 Deceleration Valve--Application of the Valve System

The application to various engines and vehicles is not significantly different.

5.0 Anti-Dieseling Solenoid or Idle Stop Solenoid

Idle Stop Solenoid

The idle stop solenoid is mounted on the carburetor to prevent engine operation after the engine is shut off (dieseling).

The solenoid eliminates this dieseling, by fully closing the throttle valve(s) when the ignition is turned off.

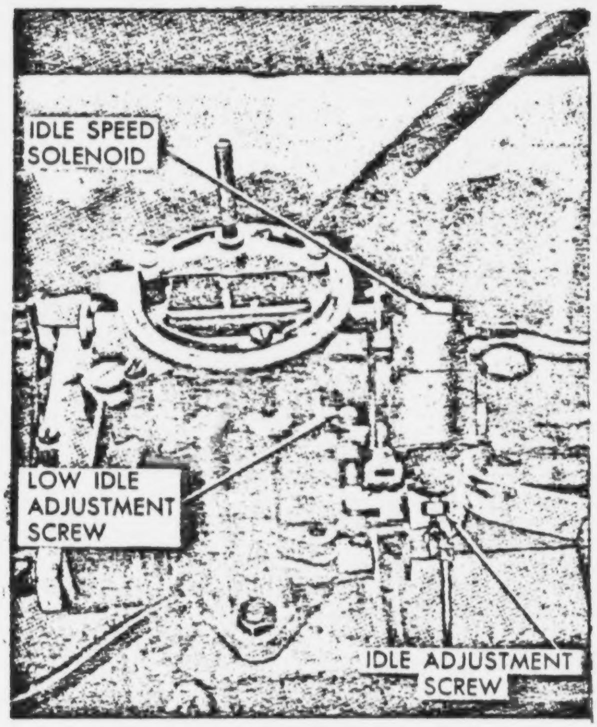
When the ignition switch is turned on, the solenoid coil is activated and the plunger is driven to its full extended position. The plunger acts on the throttle valve lever, and, sets the throttle valve(s) in a position to achieve specified idle rpm.

When the ignition is turned off, the solenoid is de-energized and the plunger retracts into the solenoid, causing the throttle valve(s) to close to a position controlled by a low idle adjusting screw. At this point the throttle valve(s) is open only enough to allow the engine to run at a much lower rpm. This lower setting keeps the throttle valve(s) from completely closing and scuffing the throttle bore(s).

The lower idle speed setting is made with a set screw when the solenoid is electrically disconnected. The setting for normal idle speed is adjusted, with the solenoid energized, through the hex screw in the plunger and/or by repositioning the solenoid in its mounting clamp.

Unburned gases contain undesirable amounts of hydro-carbons, predominantly during idle operation. One would naturally think that if the idle mixture is made as lean as possible, exhaust emission would be reduced. This is true up to a point. However, if the idle mixture is made too lean, the hydro-carbon content may increase above acceptable limits due to misfire.

5.0 Anti-Dieseling Solenoid or Idle Stop Solenoid


IDLE SPEED SOLENOID
LOW IDLE ADJUSTMENT SCREW
IDLE ADJUSTMENT SCREW

Idle stop solenoid

5.10 Anti-Dieseling Solenoid or Idle Stop Solenoid

BILL OF MATERIAL

Part	Material	Weight	Mat Costs	Labor Costs	Labor Overhead	Mfg Costs	Reference
ISS Valve	Assem	.300	-	.0750	.0300	.1050	17052388
Valve Cap	Steel	.050	.010	.0156	.0062	.0318	
Coil	Copper	.150	.150	.0625	.0250	.2375	
Plunger	Steel	.050	.010	.0312	.0125	.0537	
Seat	P Metal	.025	.025	.0312	.0125	.0687	
Adj Screw	Steel	.025	.005	.0156	.0062	.0268	
Total			.200	.2311	.0924	.5235	
Hose	Rubber	.200	.0400	.0078	.0031	.0509	
Mtg Bracket	Steel	.100	.0200	.0312	.0125	.0637	
Valve & Parts			.2600	.2701	.1080	.6381	
Vehicle Assembly				.0750	.0300	.1050	
Engine Modification				.0250	.0100	.0350	
Total Valve Parts & Vehicle				.3701	.1480	.7781	

5.20 Anti-Dieseling Solenoid or Idle Stop Valve Tooling Costs--Amortization Per Piece

Part	Economic Volume	1 Year Recurring Tooling	3 Year Non-Recurring Tooling	12 Year Machine & Equipment	12 Year Launching Costs	40 Year Land & Buildings	Amortization Total Per Piece
		.0100	.0080	.0050	.0005		.0235
ISS Valve	1,000,000	10,000	24,000	60,000	6,000	-	
		.0100	.0200	.0100	.0010		.0410
Valve Cap	2,000,000	20,000	120,000	120,000	12,000	-	
		.0100	.0200	.0300	.0030		.0630
Coil	2,000,000	20,000	120,000	180,000	18,000	-	
		.0025	.0050	.0020	.0002		.0097
Plunger	4,000,000	10,000	60,000	96,000	9,600	-	
		.0025	.0020	.0012	.0001		.0058
Seat	4,000,000	10,000	24,000	60,000	6,000	-	
		.0025	.0020	.0012	.0001		.0058
Adj. Screw	4,000,000	10,000	24,000	60,000	6,000	-	
Total		.0375	.0570	.0494	.0049		.1488
		.004	.0017	.0025	.0002		.0084
Hoses	5,000,000	20,000	25,000	150,000	15,000		
		.0025	.0030	.0009	.0001		.0065
Bracket	4,000,000	10,000	36,000	45,000	4,500		
Total (Sub)							
		.0167	.0333	.0056	.0006		.0562
Vehicle Assy	300,000	5,000	30,000	20,000	2,000		
		.0333	.0222	.0130	.0014		.0708
Engine Mod	300,000	10,000	20,000	50,000	5,000		
Total Vehicle							

R&D Estimate: 100,000 for 2 years, using 3 year payback for 300,000/year - .1111

5.30 Anti-Dieseling Solenoid or Idle Stop Valve

TOTAL MANUFACTURING VALVE

Part	Mat	Labor	Plant Overhead 0.40	Plant Mfg Costs	Tooling Exp.	Tooling Inv.	.20 MC Corp G/A	.20 MC Corp Profit	Vendo Plant Costs
ISS Valve	.2000	.2311	.0924	.5235	.0945	.0543	.1047	.1047	.8817
Hose	.0400	.0078	.0031	.0509	.0057	.0027	.0102	.0102	.0797
Bracket	.0200	.0312	.0125	.0637	.0055	.0010	.0127	.0127	.0956

5.40 Anti-Dieseling Solenoid or Idle Stop Solenoid

RETAIL PRICE EQUIVALENT
AT THE VEHICLE LEVEL

Part	Plant Vendor S. P.	R&D	Tools and Equip	Corp. Alloc. 20%	Corp. Profit 20%	Dealer Markup	Vehicle Retail Price Equiv
ISS Valve	.8817	.1111	-0-	.1763	.1763	.3527	1.6981
Hoses	.0797	-0-	-0-	.0159	.0159	.0319	.1434
Clamp	.0956	-0-	-0-	.0191	.0191	.0382	.1721
Vehicle	.1050		.0562	.0210	.0210	.0420	.2452
Engine Mod.	.0350	0	.0708	.0070	.0070	.0140	.1338
				Total Vehicle System Retail Price Equivalent			2.3926

5.50 Anti-Dieseling Solenoid or Idle Stop Solenoid Cost Methodology

The weight data were estimated by comparison to other similar valves. The material costs are compiled using the 1977 AMM mill price data allowing for scrap.

The labor costs are estimates of production costs using today's technology with a relatively high level of automation. The overhead costs and corporate allocation data were obtained from a manufacturer in the industry.

The tooling costs are estimates of the expendable tooling, jigs, fixtures, and dies, as well as, machinery and equipment.

No land and building costs were included.

The vehicle and engine modification costs are estimates, based on judgment of the degree of changes made by the engine manufacturer.

5.60 Anti-Dieseling Solenoid Cost Comparison to Aftermarket Selling Prices

Using data from the Oldsmobile parts list, the aftermarket selling price is:

	Price	Reference
Solenoid	12.65	1.7052388
Discount 1/4	3.16	
Discount 1/5	2.53	

The estimated vendor costs are $ .8817.The vehicle retail price equivalent is $1.6670.

5.70 Application of the Idle Stop Valve on Various Engines

The valve is an integral part of the carburetor thus variations between engine sizes are not significant.

6.0 Air Injection System

Air Pump Systems--American Motors Air Guard, Chrysler Air Injection, Ford Thermactor & General Motors Air Injection Reactor (A.I.R.)

All air pump systems, Figures 1 and 2, consist of an air injection pump, air injection tubes (one for each cylinder), a mixture control or backfire by-pass valve (added in 1966, '67), a diverter or air by-pass valve (added in 1968), check valves (one for in-line engines, two for V-8 engines), air manifolds, pipes and hoses necessary to connect the various components.

Carburetors and distributors for engines with an air pump system are designed especially for these engines; and, they should not be interchanged with, or replaced by, carburetors or distributors for engines without the air pumps.

The air injection pump, Figures 3, 4, and 5, compresses the air and injects it through the air manifolds, hoses, and injection tubes into the exhaust system, in the area of the exhaust valves. The fresh air burns with the unburned portion of the exhaust gases, thus minimizing CO and HC content of the exhaust.

The mixture control or backfire by-pass valve, when triggered by a sharp increase in manifold vacuum (as when the throttle is suddenly closed), supplies the intake manifold with fresh filtered air, to lean out the fuel-air mixture and prevent exhaust system backfire.

The diverter or air by-pass valve, Figures 6 and 7, when similarly triggered by a sharp increase in manifold vacuum, shuts off the injected air to the exhaust ports; and, helps to prevent backfiring during this period, when the mixture is exceptionally rich. During engine overrun, all the air from the pump is dumped through the muffler on the diverter or air by-pass valve. At high engine speeds, the pump produces more air than the engine can use, and the excess is dumped through the pressure relief valve, when that valve is part of the air pump, Figures 3 and 4, or, through the diverter or air by-pass valve when the pressure relief valve is part of that valve, Figure 7.

The check valve or valves prevent exhaust gases from entering and damaging the air injection pump, as back flow can occur even under normal operating conditions.

When properly installed and maintained, the system will effectively reduce exhaust emissions. However, if any system components or any engine component that operates in conjunction with the air pump system should malfunction, exhaust emissions might increase.

Because of the relationship between engine operating condition and unburned exhaust gases, the condition of the engine and tune-up should be checked whenever the air pump system seems to be malfunctioning. Particular care should be taken in checking items that affect fuel-air ratio, such as crankcase ventilation system (PCV), the carburetor and carburetor air cleaner.

6.0 Air Injection Systems

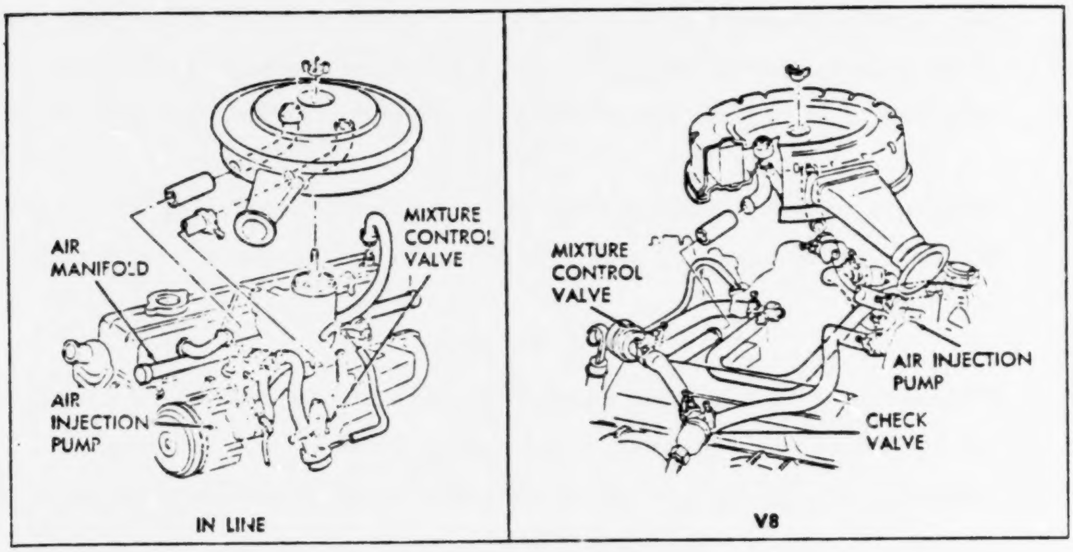

AIR MANIFOLD
MIXTURE CONTROL VALVE
AIR INJECTION PUMP
IN LINE
MIXTURE CONTROL VALVE
AIR INJECTION PUMP
CHECK VALVE
V8

Fig. 1 Typical installation of an air pump system with a mixture control valve, otherwise known as a backfire by-pass valve

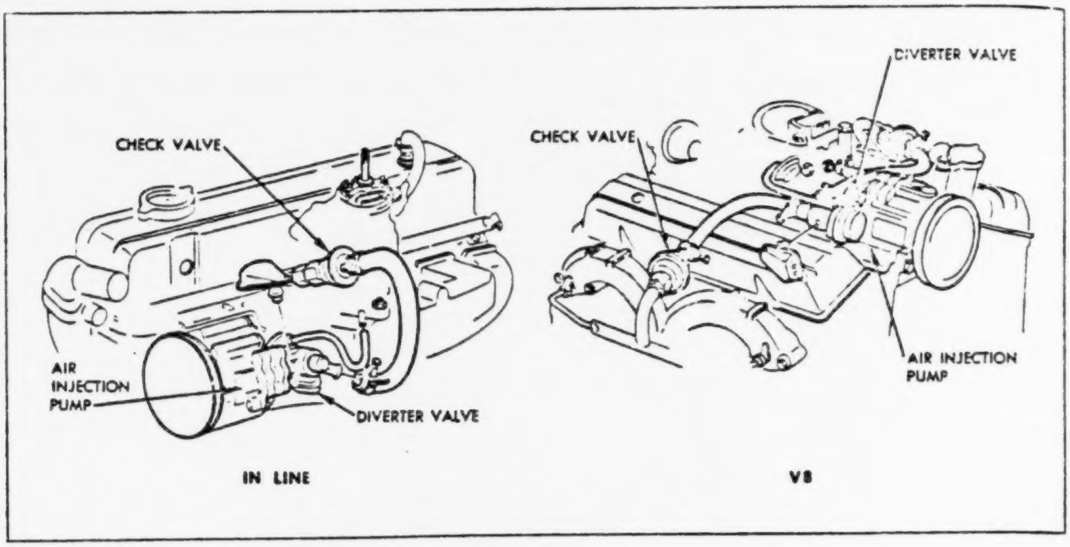

CHECK VALVE
AIR INJECTION PUMP
DIVERTER VALVE
IN LINE
DIVERTER VALVE
CHECK VALVE
AIR INJECTION PUMP
V8

Fig. 2 Typical installation of an air pump system with a diverter valve, otherwise known as an air by-pass valve. 1968-73

6.0 Air Injection Systems

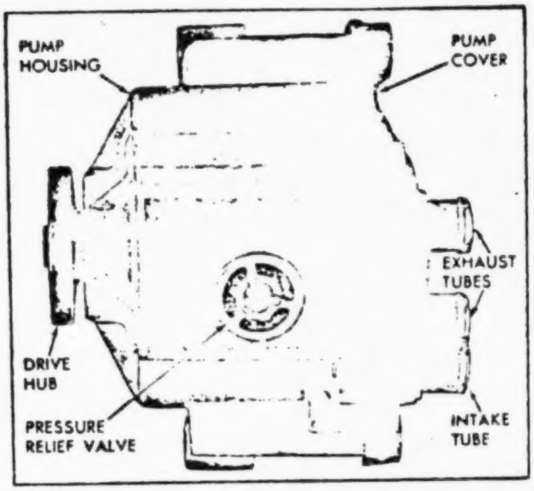

PUMP HOUSING
PUMP COVER
EXHAUST TUBES
DRIVE HUB
PRESSURE RELIEF VALVE
INTAKE TUBE

Fig. 3 Air injection pump with separate air filter. 1966-67

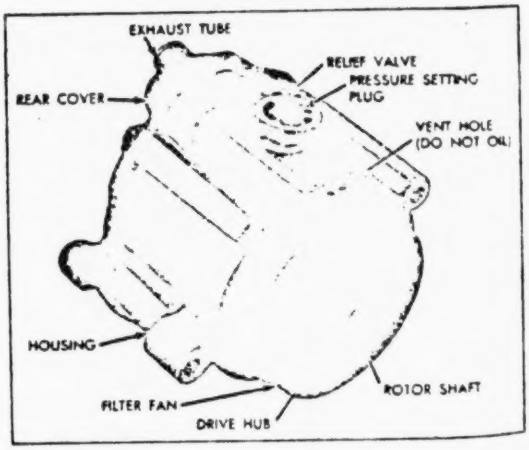

EXHAUST TUBE
RELIEF VALVE
PRESSURE SETTING PLUG
REAR COVER
VENT HOLE (DO NOT OIL)
HOUSING
ROTOR SHAFT
FILTER FAN
DRIVE HUB

Fig. 4 Air injection pump with integral centrifugal air filter. Starting 1968

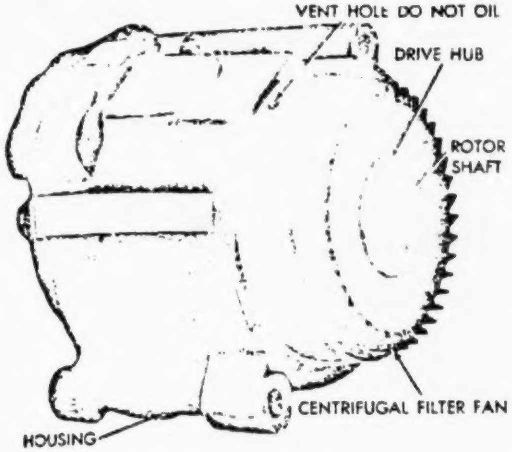
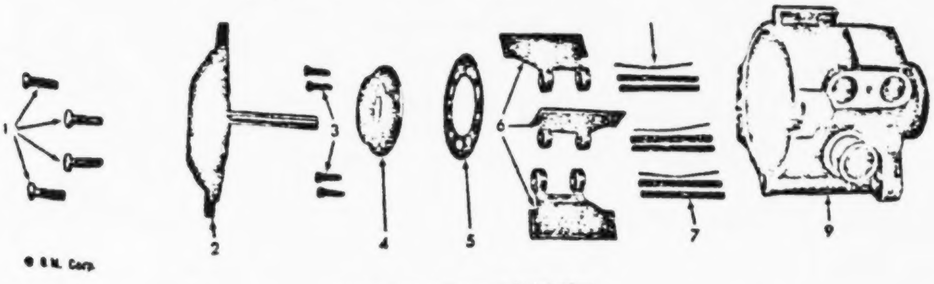

VENT HOLE DO NOT OIL
DRIVE HUB
ROTOR SHAFT
CENTRIFUGAL FILTER FAN
HOUSING

Fig. 5 Air injection pump with integral centrifugal air filter without pressure valve


1
2
3
4
5
6
7
9
© G.M. Corp.

All Injection pump—exploded view

1 Cover attaching bolts
2 Cover assembly
3 Rear rotor ring screws
4 Rear rotor ring and bearing assembly
5 Rear carbon seal
6 Vane assemblies
7 Vane shoes
8 Shoe springs
9 Housing and assemblies

6.0 Air Injection Systems

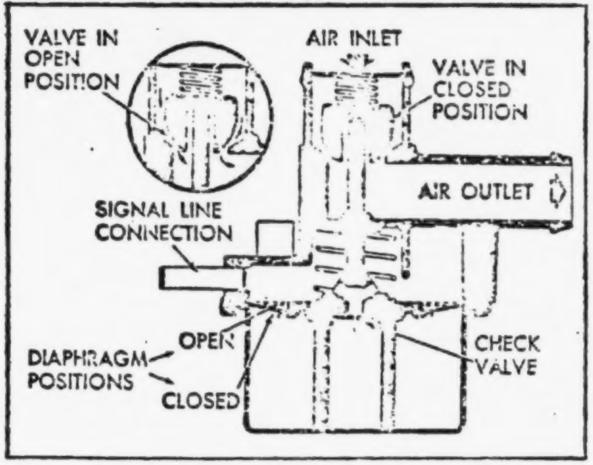

VALVE IN
OPEN
POSITION
AIR INLET
VALVE IN
CLOSED
POSITION
AIR OUTLET
SIGNAL LINE
CONNECTION
OPEN
DIAPHRAGM
POSITIONS
CLOSED
CHECK
VALVE

Fig. 6 Typical mixture control or backfire by-pass valve

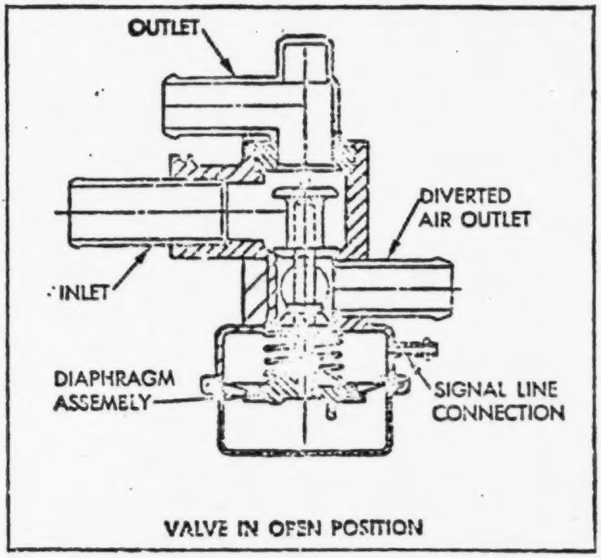

OUTLET
DIVERTED
AIR OUTLET
INLET
DIAPHRAGM
ASSEMELY
SIGNAL LINE
CONNECTION
VALVE IN OPEN POSITION

Fig. 7 Typical diverter or air by-pass valve

6.0 Air Injection Systems

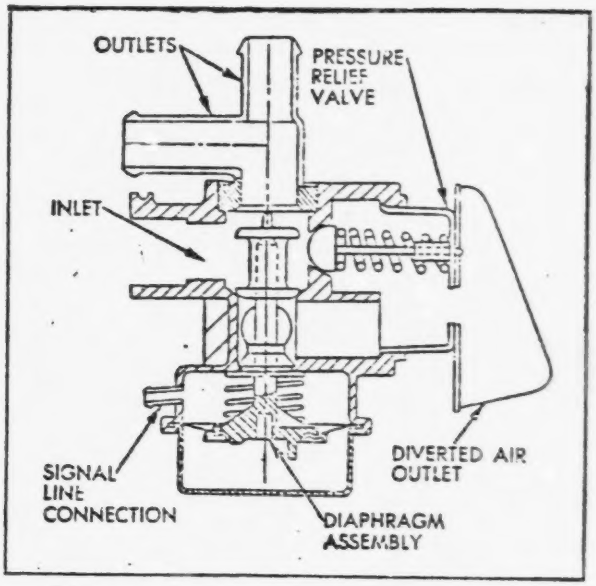

OUTLETS
PRESSURE RELIEF VALVE
INLET
DIVERTED AIR OUTLET
SIGNAL LINE CONNECTION
DIAPHRAGM ASSEMBLY

Fig. 8 Typical diverter or air by-pass valve with integral pressure relief valve

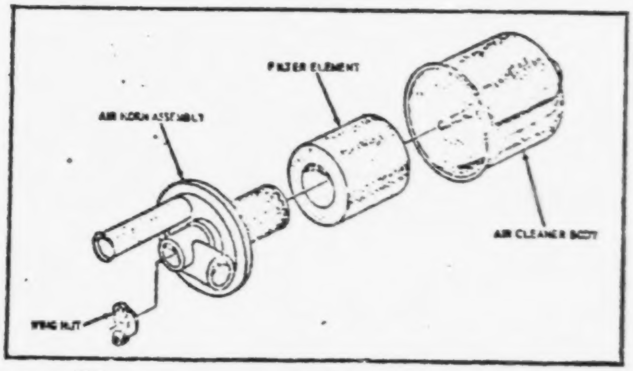
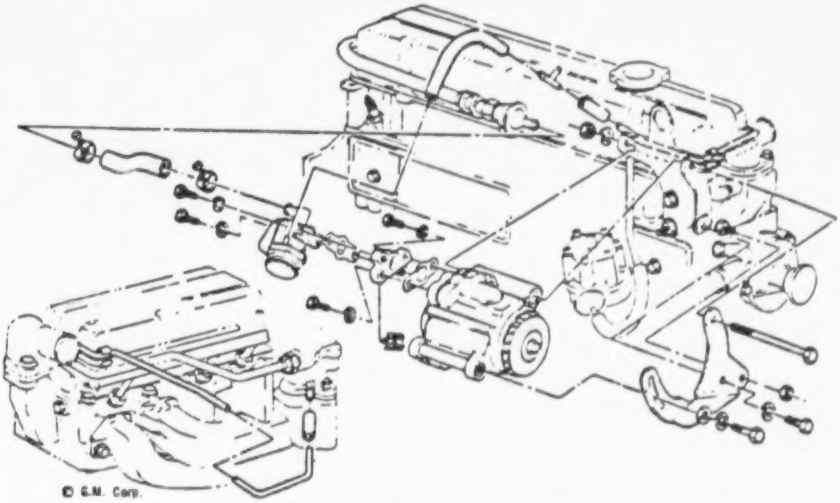

FILTER ELEMENT
AIR HORN ASSEMBLY
AIR CLEANER BODY
WING NUT

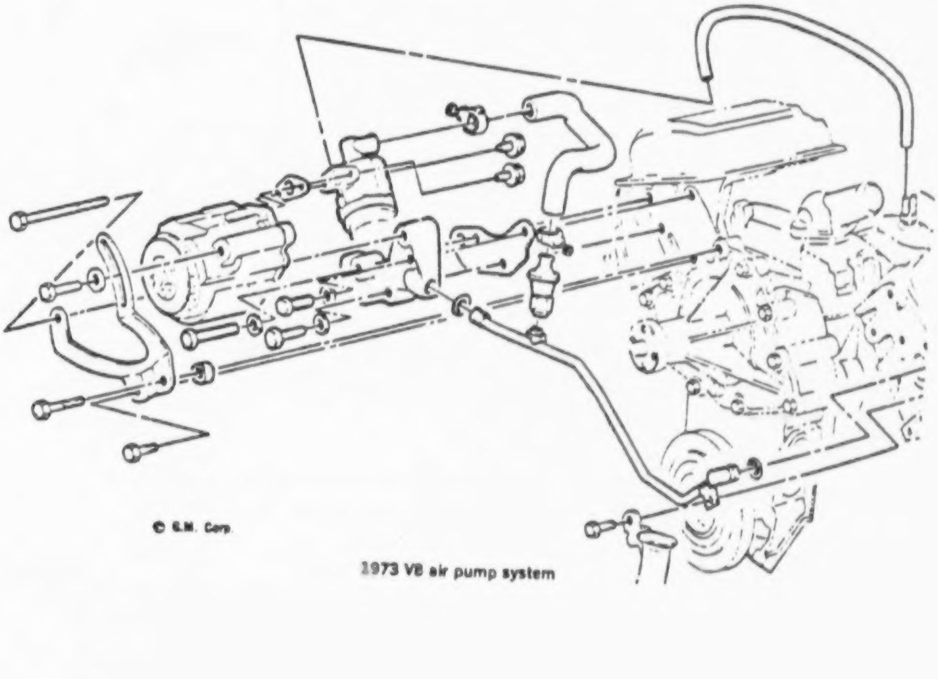
Fig. 9 Conventional type pump air filter

Pontiac

Fig. 10 - **AIR PUMP SYSTEM—CONT'D**



1973 six cylinder air pump installation. 1972 is similar



1973 V8 air pump system

6.1 Air Injection System

BILL OF MATERIAL

	Material	Weight	Mat Costs	Labor	Labor Overhead	Mfg Costs	Reference
Pump Assem	Assem	7.690	-	.1250	.0500	.1750	07817806
Housing	Alum	3.500	2.1000	.1250	.0500	2.2750	
Hub	Steel	.200	.0400	.0625	.0250	.1275	
Shaft	Steel	.090	.0180	.0312	.0125	.0617	
Cover	Alum	1.000	.6000	.0625	.0250	.6875	
Rotor	Steel	.300	.0600	.0312	.0125	.1037	
Bearings	Steel	.400	.2000	.0625	.0250	.2875	
Vanes	PM	.300	.1200	.0625	.0250	.2075	
Vane Shoes	PM	.100	.0400	.0312	.0125	.0837	
Shoe Springs	Steel	.050	.0100	.0156	.0062	.0318	
Carbon Seal	PM	.100	.0400	.0156	.0062	.0618	
Tubes	Steel	.300	.0600	.0156	.0062	.0818	
Relief Valve	Steel	.150	.0300	.1250	.0500	.2050	
Hardware	Steel	.200	.0400	.0156	.0062	.0618	
Fan	Plastic	1.000	.8000	.0625	.0250	.8875	
			4.1580	.8435	.3373	5.3388	
Air Manifold	Steel	2.000	1.0000	.0625	.0250	1.0875	
Hoses	Rubber	0.500	.1000	.0312	.0125	.1437	
Pipes	Steel	.300	.0600	.0156	.0062	.0818	
A I Tubes	Steel	1.000	.5000	.0312	.0125	.5437	
Pulley	Steel	.950	.1900	.0625	.0250	.2775	03927116
Mtg. Brkt	Steel	2.590	.5180	.0625	.0250	.6055	4027214
Hardware	Steel	1.500	.3000	.0156	.0062	.3218	
A/P Bracket	Steel	.250	.0500	.0312	.0125	.0937	
A/P Belt	Rubber	.230	.0460	.0156	.0062	.0678	4027350
			2.7640	.3279	.1311	3.2230	

6.1 Air Injection System and Bill of Material (cont'd)

Part	Material	Weight	Mat Costs	Labor	Labor Overhead	Mfg Costs	Reference
Valve Hoses	Rubber	1.000	.2000	.0625	.0250	.2875	
Clamps	Steel	.200	.0400	.0156	.0062	.0618	
Vehicle Assem	-	-	-	.3750	.1500	.5250	
Engine Mod	-	-	-	.1250	.0500	.1750	
Assem Vehicle						1.0493	
Total Vehicle A I-System						9.6111	

6.1 Air Injection System
Valves and Filter

BILL OF MATERIAL

Part	Material	Weight	Mat Costs	Labor	Labor Overhead	Mfg Costs	Reference
Air Pump Filter	Assem	.300		.0312	.0125	.0437	See Sketch
Air Horn	Steel	.100	.0200	.0625	.0250	.1075	
Filter	Paper	.100	.0400	.0312	.0125	.0837	
Body	Steel	.100	.0200	.0156	.0062	.0418	
			.0800	.1405	.0562	.2767	
Mix Contr. Vlv	Assem	.890	-	.1250	.0500	.1750	3769895
Valve	PM	.090	.0360	.0625	.0250	.1235	27.95
Valve Spring	Steel	.100	.0200	.0156	.0062	.0418	
Housing	Steel	.200	.0400	.0625	.0250	.1275	
Diaphragm	Copper	.100	.0800	.0312	.0125	.1237	
Cap	Steel	.200	.0400	.0312	.0125	.0837	
Diaphragm Spr	Steel	.100	.0200	.0156	.0062	.0418	
Pin	Steel	.100	.0200	.0625	.0250	.1075	
			.2560	.4061	.1624	.8245	
Diverter & Relief Valve	Assem	1.230	-	.1250	.0500	.1750	7043229 14.80
Housing	Steel	.500	.1000	.0625	.0250	.1875	3671044
Pin & Valve	Steel	.250	.0500	.0312	.0125	.0937	16.60
Spring	Steel	.125	.0250	.0156	.0062	.0468	
Diaphragm	Copper	.125	.1000	.0312	.0125	.1437	
Relief Valve	PM	.052	.0200	.0312	.0125	.0637	04974265
Rel Vlve Spr	Steel	.063	.0120	.0156	.0062	.0338	4.80
Rel Vlve Cover	Steel	.115	.0230	.0312	.0125	.0667	
			.3300	.3435	.1374	.8109	

6.2 Air Injection System

Tooling Costs

Amortization Per Part

Part	Economic Volume	1 Year Recurring Tooling	3 Year Non-Recurring Tooling	12 Year Machinery & Equip	12 Year Launching Costs	40 Year Land & Buildings	Amortization Per Piece
		.0020	.0020	.0020	.0002		.0062
Valve Hoses	5,000,000	10,000	30,000	120,000	12,000	-	
		.0050	.0050	.0030	.0003		.0133
Clamps	10,000,000	50,000	150,000	360,000	36,000	-	
		.1000	.1000	.1000	.0100		.3100
Vehicle Assem	300,000	30,000	90,000	360,000	36,000	-	
		.1000	.1000	.1000	.0100		.3100
Engine Mod	300,000	30,000	90,000	360,000	36,000	-	
Assem Vehicle							.6395
Total A I System							1.5996

6.2 Air Injection System--Tooling Costs--Amortization Per Part

Part	Economic Volume	1 Year Recurring Tooling	3 Year Non-Recurring Tooling	12 Year Machinery & Equip	12 Year Launching Costs	40 Year Land & Buildings	Amortization Per Piece
		.0200	.0333	.0400	.0040	.0250	.1223
Pump Assem	5,000,000	100,000	500,000	2,400,000	240,000	5,000,000	
		.0400	.0667	.0833	.0083		.1983
Housing	5,000,000	200,000	1,000,000	5,000,000	500,000		
		.0100	.0200	.0100	.0010		.0410
Hub	5,000,000	50,000	300,000	600,000	60,000		
		.0020	.0020	.0020	.0002		.0062
Shaft	5,000,000	10,000	30,000	120,000	12,000		
		.0100	.0167	.0167	.0017		.0450
Cover	5,000,000	50,000	250,000	1,000,000	100,000		
		.0040	.0020	.0020	.0002		.0082
Rotor	5,000,000	20,000	30,000	120,000	12,000		
		.0050	.0050	.0083	.0008		.0191
Bearings	10,000,000	50,000	150,000	1,000,000	100,000		
		.0040	.0080	.0067	.0007		.0193
Vanes	15,000,000	60,000	360,000	1,200,000	120,000		
		.0010	.0040	.0033	.0003		.0086
Vane Shoes	30,000,000	30,000	360,000	1,200,000	120,000		
		.0007	.0013	.0007	.0001		.0027
Shoe Springs	30,000,000	20,000	120,000	240,000	24,000		
		.0020	.0020	.0020	.0002		.0062
Carbon Seal	5,000,000	10,000	30,000	120,000	12,000		
		.0013	.0008	.0003	-		.0028
Tubes	15,000,000	20,000	36,000	60,000	6,000		
		.0100	.0080	.0060	.0006		.0246
Relief Valve	5,000,000	50,000	120,000	360,000	36,000		
		.0067	.0067	.0056	.0006		.0194
Hardware	15,000,000	100,000	300,000	1,000,000	100,000		
		.0040	.0024	.0020	.0002		.0086
Fan	5,000,000	20,000	36,000	120,000	12,000		
							.5323

6.2 Air Injection System--Tooling Costs--Amortization Per Part

	Economic Volume	1 Year Recurring Tooling	3 Year Non-Recurring Tooling	12 Year Machinery & Equip	12 Year Launching Costs	40 Year Land & Buildings	Amortization Per Piece
		.0100	.0100	.0020	.0002		.0222
Mix Cont Valve	2,500,000	25,000	75,000	60,000	6,000	-	
		.0100	.0100	.0040	.0004		.0244
Valve	2,500,000	25,000	75,000	120,000	12,000		
		.0020	.0020	.0010	.0001		.0051
Valve Spring	5,000,000	10,000	30,000	60,000	6,000		
		.0100	.0100	.0040	.0004		.0244
Housing	2,500,000	25,000	75,000	120,000	12,000		
		.0040	.0040	.0020	.0002		.0102
Diaphragm	2,500,000	10,000	30,000	60,000	6,000		
		.0100	.0100	.0020	.0002		.0222
Cap	2,500,000	25,000	75,000	60,000	6,000		
		.0100	.0020	.0010	.0001		.0131
Diaphragm Spr	5,000,000	50,000	30,000	60,000	6,000		
		.0020	.0020	.0006	.0001		.0047
Pin	5,000,000	10,000	30,000	36,000	3,600		
		.0580	.0500	.0166	.0017		.1263
		.0100	.0100	.0020	.0002		.0222
Div & Rel Valve	2,500,000	25,000	75,000	60,000	6,000		
		.0100	.0100	.0040	.0004		.0244
Housing	2,500,000	25,000	75,000	120,000	12,000		
		.0200	.0200	.0040	.0004		.0444
Pin & Valve	2,500,000	50,000	150,000	120,000	12,000		
		.0020	.0020	.0010	.0001		.0051
Spring	5,000,000	10,000	30,000	60,000	6,000		
		.0040	.0040	.0020	.0002		.0102
Diaphragm	2,500,000	10,000	30,000	60,000	6,000		
		.0100	.0100	.0020	.0002		.0222
Relief Valve	5,000,000	50,000	150,000	120,000	12,000		
		.0020	.0020	.0010	.0001		.0051
Rel Valve Spr	5,000,000	10,000	30,000	60,000	6,000		
		.0040	.0040	.0020	.0002		.0102
Rel Vlve Cover	2,500,000	10,000	30,000	60,000	6,000		
		.0620	.0620	0180	[illegible]		[illegible]

6.2 Air Injection System--Tooling Costs--Amortization Per Part

Part	Economic Volume	1 Year Recurring Tooling	3 Year Non-Recurring Tooling	12 Year Machinery & Equip	12 Year Launching Costs	40 Year Land & Buildings	Amortization Per Piece
		.0100	.0067	.0042	.0004	–	.0212
Air Manifold	1,000,000	10,000	20,000	50,000	5,000		
		.0040	.0017	.0025	.0002		.0084
Hoses	5,000,000	20,000	25,000	150,000	15,000	–	
		.0020	.0008	.0008	.0001		.0038
Pipes	5,000,000	10,000	12,500	50,000	5,000	–	
		.0060	.0060	.0020	.0002		.0142
A I Tubes	5,000,000	30,000	90,000	120,000	12,000	–	
		.0100	.0050	.0025	.0002		.0177
Pulley	2,000,000	20,000	30,000	60,000	6,000		
		.0100	.0050	.0025	.0002		.0177
Mtg Bracket	2,000,000	20,000	30,000	60,000	6,000		
		.0100	.0040	.0020	.0002		.0162
Hardware	5,000,000	50,000	60,000	120,000	12,000		
		.0100	.0050	.0025	.0002		.0177
A/P Bracket	2,000,000	20,000	30,000	60,000	6,000		
		.0020	.0020	.0010	.0001		.0051
A/P Belt	5,000,000	10,000	30,000	60,000	6,000		
		.0640	.0362	.0200	.0018		.1220
		.0020	.0020	.0010	.0001		.0051
Air Pump Filter	5,000,000	10,000	30,000	60,000	6,000		
		.0040	.0040	.0020	.0002		.0102
Air Horn	5,000,000	20,000	60,000	120,000	12,000		
		.0040	.0040	.0020	.0002		.0102
Filter	5,000,000	20,000	60,000	120,000	12,000		
		.0040	.0040	.0020	.0002		.0102
Body	5,000,000	20,000	60,000	120,000	12,000		
		.0140	.0140	.0070	.0007		.0357

6.3 Air Injection System

TOTAL MANUFACTURING COSTS

Part	Mat	Labor	Plant Over-Head	Plant Costs	Tooling Exp.	Tooling Inv.	.20 MC Corp	.20 MC Corp Profit	Mfg/ Vendor Costs
Pump	3.3280	.5310	.2124	4.0714	.2085	.1489	.8143	.8143	6.0574
Pump Assem	.0000	.1250	.0500	.1750	.0533	.0690	.0350	.0350	.3673
Relief Valve	.0300	.1250	.0500	.2050	.0180	.0066	.0410	.0410	.3116
Fan	.8000	.0625	.0250	.8875	.0064	.0022	.1775	.1775	1.2511
Air Manifold	1.0000	.0625	.0250	1.0875	.0167	.0046	.2175	.2175	1.5438
Hoses	.1000	.0312	.0125	.1437	.0057	.0027	.0287	.0287	.2095
Pipes & Tubes	.5600	.0468	.0187	.6255	.0148	.0031	.1251	.1251	.8936
Pulley	.1900	.0625	.0250	.2775	.0150	.0027	.0555	.0555	.4062
Belt	.0460	.0156	.0062	.0678	.0040	.0011	.0135	.0135	.1000
Mktg. Brkts.	.5680	.0937	.0375	.6992	.0300	.0054	.1398	.1398	1.0143
Hardware	.3000	.0156	.0062	.3218	.0140	.0022	.0644	.0644	.4667
Air Injec & Pump	6.9220	1.1714	.4685	8.5619					12.6215
Air Pump Filter	.0800	.1405	.0562	.2767	.0280	.0077	.0553	.0553	.4231
Mix Contr Vlve	.2560	.4061	.1624	.8245	.1080	.0183	.1649	.1649	1.2006
Diverter & Relief Valve	.3300	.3435	.1374	.8109	.1240	.0198	.1622	.1622	1.2791
Valve Hoses	.2000	.0625	.0250	.2875	.0040	.0022	.0575	.0575	.4087
Clamps	.0400	.0156	.0062	.0618	.0100	.0033	.0124	.0124	.0998
Total AI System									16.1128

6.4 Air Injection System

RETAIL PRICE EQUIVALENT
AT THE VEHICLE LEVEL

Part	Plant Vendor Costs	R&D	Tools & Equip	Corp. Alloc	Corp. Profit	Dealer Markup	Vehicle Retail Price Equivalent
AI Pump	12.6215	1.000		2.5243	2.5243	5.0486	23.7187
AI Valves	3.4913	-	-	.6983	.6983	1.3965	6.2843
Vehicle Assem	.5250	-	.3100	.1050	.1050	.2100	1.2550
Engine Mod.	.1750	-	.3100	.0350	.0350	.0700	.6250
Total Vehicle Retail Price Equivalent							31.8830

R & D is estimated to be $300,000 per year. Allocated over 300,000 vehicles per year results in $1.00 per vehicle.

6.5 Air Injection System

Cost Comparison to Aftermarket Selling Prices

Using the aftermarket discount data and the aftermarket selling prices, the Air Injection System costs are:

		Disc 1/4	Disc 1/5	Estimated Vendor Costs
Air Pump Assembly	62.95	15.74	12.59	7.9874
Pulley	2.64	.66	.53	.4062
Bracket Assembly	3.60	.90	.72	1.0143
Diverter Valve	11.80	2.95	2.36	1.2791
Mixture Control Valve	14.00	3.50	2.80	1.2806

6.6 Air Injection System Cost Methodology

The weight data were obtained from both the Chrysler data and the Oldsmobile data books. The material costs are compiled using the AMM mill prices.

The labor costs are estimates based on mass production tooling and equipment. The economies of scale are specified in the tooling estimates. The overhead data are based on the information supplied from one of the automobile companies.

The tooling costs are based on mass production estimates of die, mold, and fixture costs. The equipment estimates are based on the current costs of new equipment. The land and building estimate is based on published information, on an actual production facility for General Motors.

6.70 Air Injection System

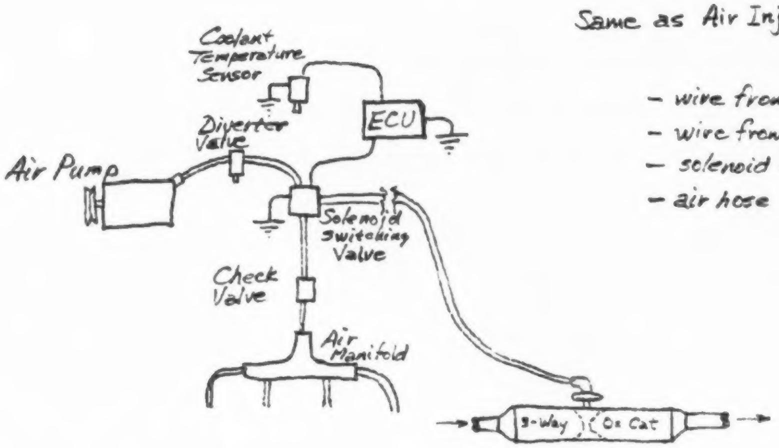
The installations in various engines, depending upon company, vary significantly. Therefore, each system cost can be constructed from the prior detail data. See the installation sketches in Section 6.0 to confirm the data.

7.0 The air switching system is a subsystem and is usually associated with the 3-way plus oxidation catalyst system. An air switching valve is added to the air injection line which supplies air to the exhaust ports. When engine coolant temperature reaches a predetermined level, the TVS allows a vacuum signal to be sent to the switching valve which in turn diverts the air being injected into the ports to a point downstream of the 3-way catalyst and just upstream of the oxidation catalyst. In vehicles utilizing electronic control units (ECU), the ECU may receive signals from a temperature sensor that indicates when engine temperature is high enough at which time the air is diverted downstream by a solenoid switching valve.

Air Switching System

Same as Air Injection System except:

- wire from CTS to ECU
- wire from ECU to solenoid
- solenoid switching valve
- air hose to point downstream


Coolant Temperature Sensor
ECU
Diverter Valve
Air Pump
Solenoid Switching Valve
Check Valve
Air Manifold
3-Way
Ox Cat

7.1 Air Switching System

BILL OF MATERIAL
MANUFACTURING COSTS

Component	Material	Weight	Mat Costs	Labor	Overhead	Mfg Costs	Reference
Solenoid Valve	Steel	.316	.0634	.2620	.1048	.4302	Sketch
Electric Wiring	Plastic Copper	.050	.0400	.0010	.0004	.0414	and EPA Data
Hose	Rubber	.300	.0600	.0300	.0120	.1020	
Total			.1634	.2930	.1212	.5736	
Vehicle Assembly				.0625	.0250	.0875	
Engine Modification				.0312	.0125	.0437	
Total Vehicle						.7048	

7.2 Air Switching System--Tooling Costs--Amortized Per Part

Part	Economic Volume Per Year	1 Year Recurring Tooling	3 Year Non-Recurring Tooling	12 Year Machinery Equipment	12 Year Launching Costs	40 Year Land & Buildings	Amortization Per Piece
Solenoid Valve	5,000,000	.0100 50,000	.0167 250,000	.0200 1,200,000	.0020 120,000	-	.0487
Wiring	5,000,000	.0004 2,000	.0002 2,500	.0002 15,000	.0000 1,500	-	.0008
Hose	5,000,000	.0040 20,000	.0017 25,000	.0025 150,000	.0002 15,000	-	.0084
Total		.0144	.0185	.0223	.0023		.0579
Vehicle Assembly	300,000	.0083 2,500	.0167 15,000	.0023 10,000	.0003 1,000	-	.0281
Engine Modification	300,000	.0167 5,000	.0111 10,000	.0028 10,000	.0003 1,000	-	.0308
Total							.1168

Research and Development Estimate: $210,000 over 3 Years, or $70,000 per year
for 300,000 vehicles per year, or .2330 per vehicle

7.3 Air Switching System

TOTAL MANUFACTURING COSTS

Part	Mat	Labor	Plant Over-Head	Plant Mfg Costs (MC)	Tooling Exp.	Tooling Inv.	.20/MC Corp Costs	.20/MC Corp Profit	Mfg/ Vendo Costs
Solenoid Valve	.0634	.2620	.1048	.4302	.0267	.0220	.0860	.0860	.6509
Wiring & Hose	.1000	.0310	.0124	.1434	.0063	.0029	.0287	.0287	.2100
Total									.8609

7.4 Air Switching System

RETAIL PRICE EQUIVALENT AT THE VEHICLE LEVEL

Part	Plant Vendor Costs (VC)	R&D	Tools and Equip	Corp Allocation .20 VC	Corp Profit .20 VC	Dealer Markup .40 VC	Vehicle Retail Price Equivalent
Solenoid Valve	.6509	.2330	-	,1302	.0302	.2604	1.4046
Wiring & Hose	.2100	-	-	.0420	.0420	.0840	.3780
Vehicle Assembly	.0875	-	.0281	.0175	.0175	.0350	.1856
Engine Modification	.0437	-	.0308	.0087	.0087	.0175	.1095
Total RPE							2.0777

7.5 Air Switching System

Cost Comparison to Aftermarket Selling Prices

This particular valve design does not have an aftermarket price in our source data (1977 catalogs). We can estimate the relative selling price by comparing selling prices for diverter valves and EGR valves ($14.00 - $18.05).

	Diverter	EGR
Aftermarket Selling Price	$14.00	$18.05
Discount (1/4 Selling Price)	3.50	4.51
Discount (1/5 Selling Price)	2.80	3.61

The vehicle retail price equivalent (RPE) is estimated to be 2.0777 while the manufacturing costs are .8609 for the valve and hoses (.6509 for the valve).

7.6 Air Switching System
Cost Methodology

The weight data is estimated using similar valve data. The valve design was assumed to be solenoid actuated.

The labor costs are estimates of production costs, using today's technology and assumed economies of scale. The tooling estimates are based on knowledge of the mass production processes and equipment.

The assembly costs and the engine modification costs were included in the costs at the vehicle level.

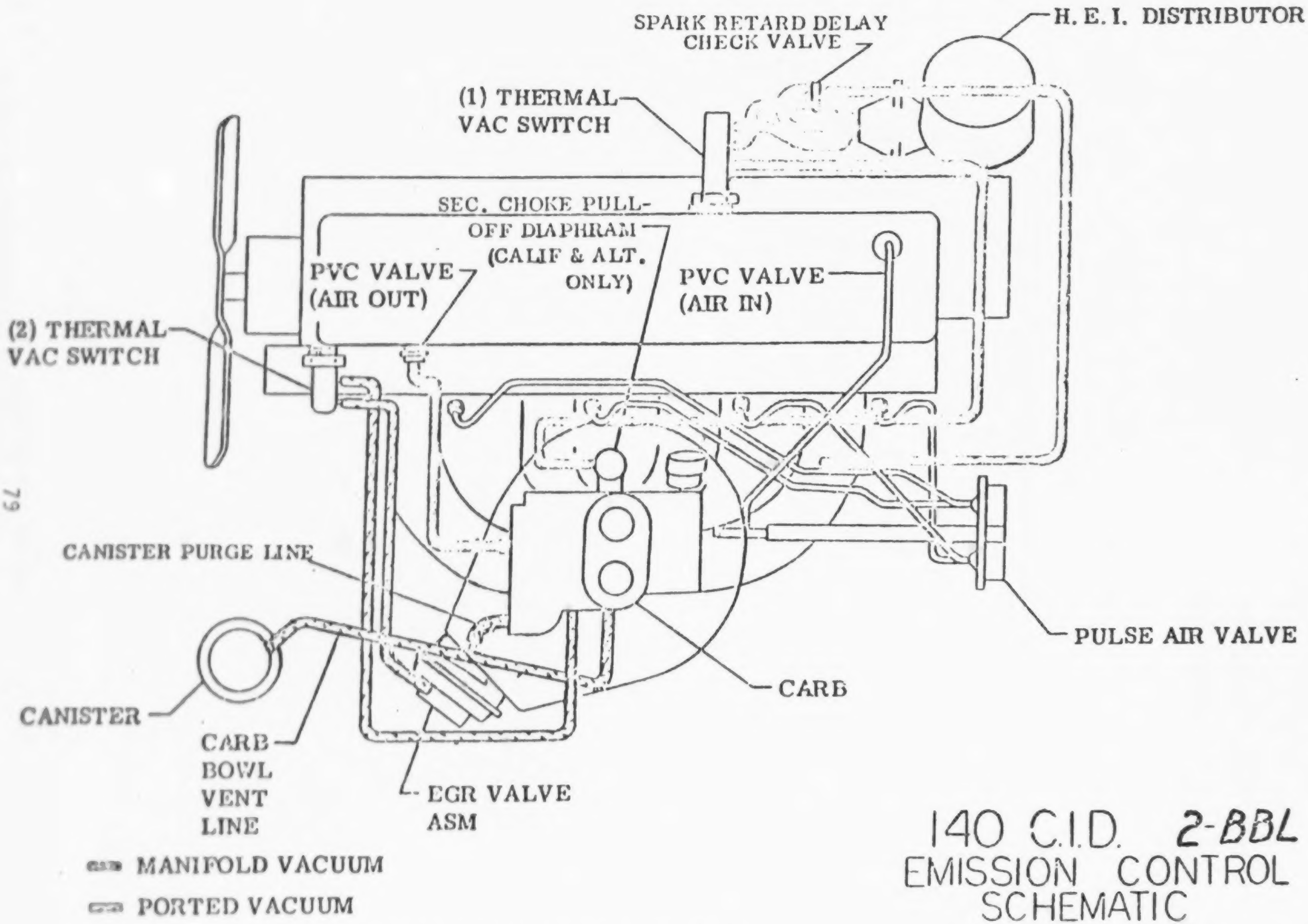
7.7 Air Switching System
Applications in Various Engine Configurations

This air switching system is assumed to be unaffected by engine size.

8.0 Reed Air Valve

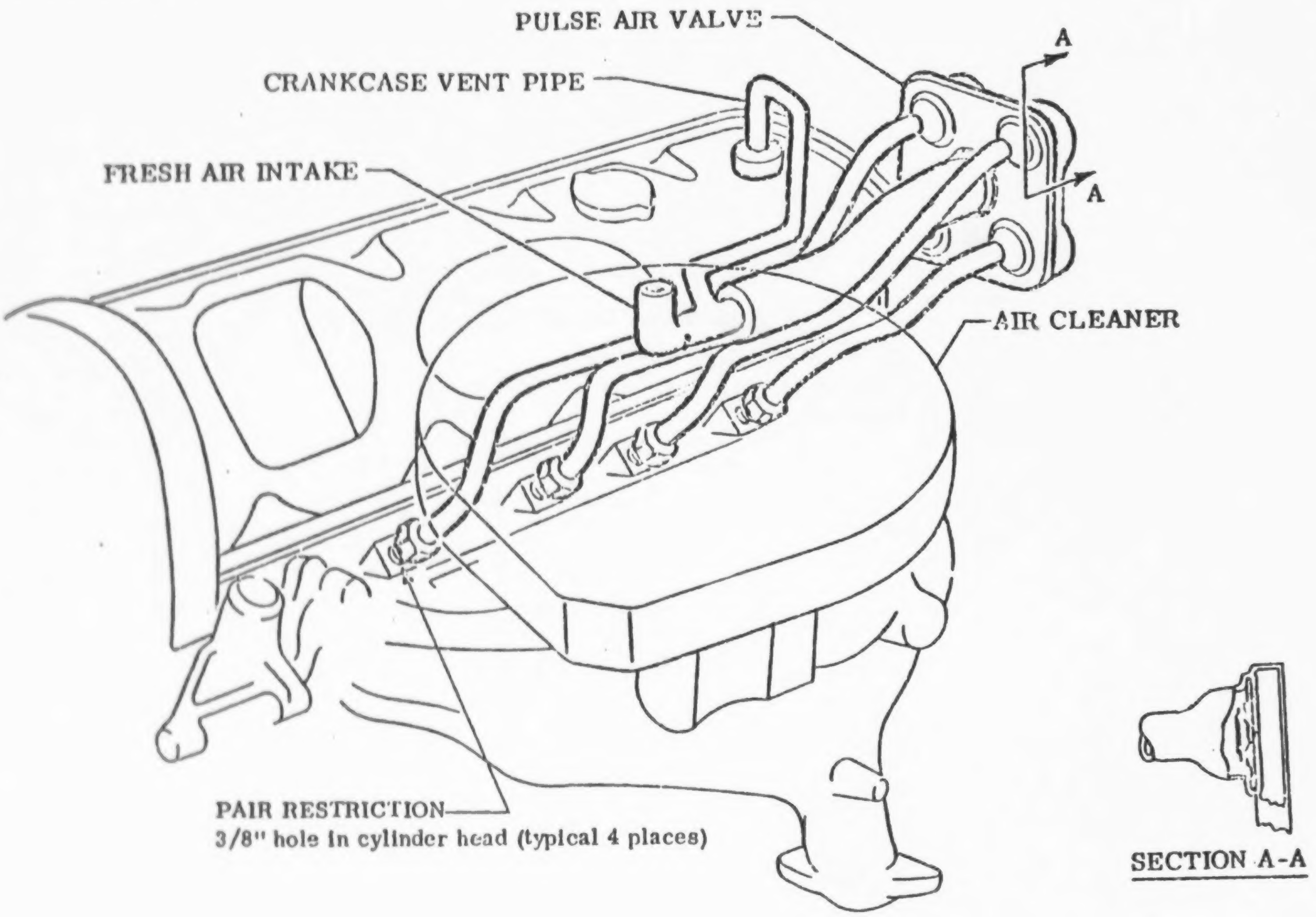
Pulse Air System

The pulse air system is a simplified reed valve system that provides an air supply to the exhaust manifold to help oxidize unburned hydrocarbons and carbon monoxide. The air suction valve takes air from the air cleaner and imposes a pulsated air flow at the exhaust valve. In some applications, this system is used in place of an air pump system when lesser amounts of air are required than which would be provided by an air pump system.


SPARK RETARD DELAY CHECK VALVE
H. E. I. DISTRIBUTOR
(1) THERMAL VAC SWITCH
SEC. CHOKE PULL-OFF DIAPHRAM (CALIF & ALT. ONLY)
PVC VALVE (AIR OUT)
PVC VALVE (AIR IN)
(2) THERMAL VAC SWITCH
CANISTER PURGE LINE
PULSE AIR VALVE
CARB
CANISTER
CARB BOWL VENT LINE
EGR VALVE ASM
MANIFOLD VACUUM
PORTED VACUUM

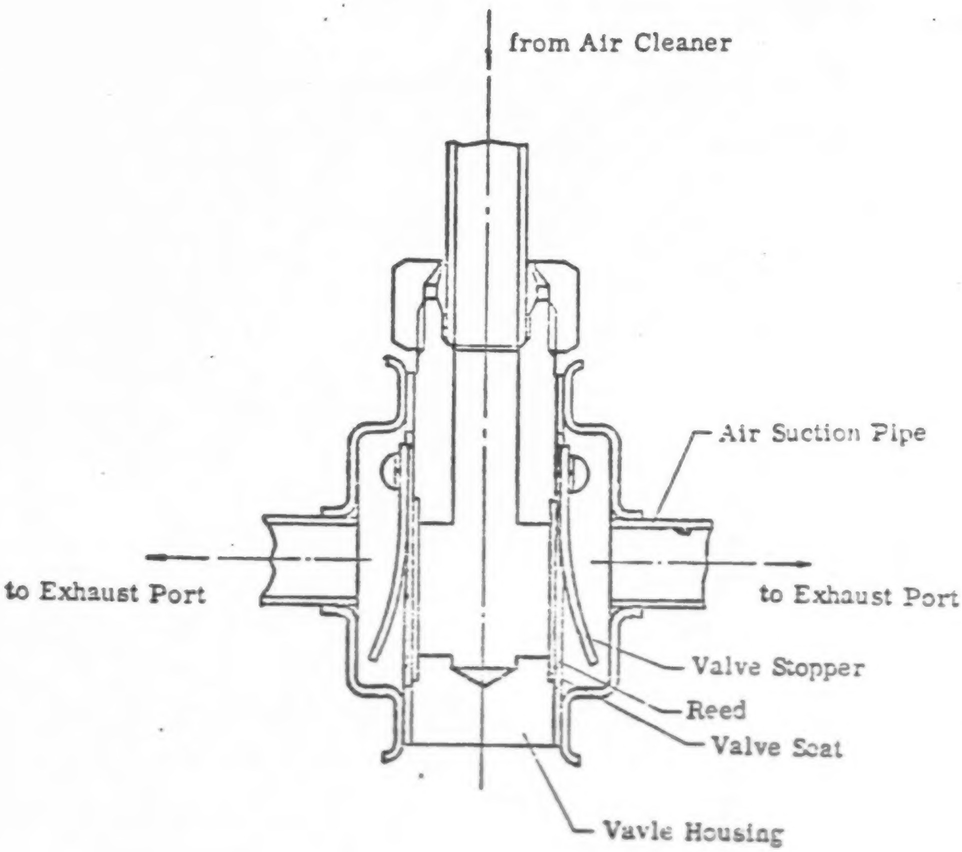
140 C.I.D. 2-BBL
EMISSION CONTROL
SCHEMATIC
P-AIR/EGR

(1) FOR TRAPPED VAC. SPARK & SEC. CHOKE PULL-OFF.
(2) FOR EGR COLD OVERRIDE.


PULSE AIR VALVE
A
CRANKCASE VENT PIPE
FRESH AIR INTAKE
A
AIR CLEANER
PAIR RESTRICTION
3/8" hole in cylinder head (typical 4 places)
SECTION A-A

1977 PULSE AIR SYSTEM 140 C.I.D. L4 ENGINE

Air Suction Valve


from Air Cleaner
Air Suction Pipe
to Exhaust Port
to Exhaust Port
Valve Stopper
Reed
Valve Seat
Vavle Housing

· **Calibrations :** **Flow resistance ; 190 - 260 ℓ/min/-500 mmAq**
Leak ; Max. 0.2 ℓ/min. /250 mmAq

8.1 Reed Air Valve
Pulse Air System

BILL OF MATERIAL
MANUFACTURING COSTS
4-CYLINDER ENGINE

Component	Material	Weight	Mat Costs	Labor	Labor Overhead	Mfg Costs	Reference
Manifold	Alum.	.50	.300	.0416	.0166	.3582	Figure B37
Reed Valve	Steel Bronze	.25	.100	.1250	.0500	.2750	
(6 ft) Suction Pipes	Steel Tubing	1.00	.300	.0312	.0125	.3437	
Fittings	Steel	.30	.120	.0312	.0125	.1637	
Air Intake	Steel Tubing	.20	.060	.0100	.0040	.0740	
		2.25	.880	.2390	.0956	1.2146	
Modify Engine Head	-	-	-	.0625	.0250	.0875	
Vehicle Assembly	-	-	-	.1250	.0500	.1750	
Total Vehicle Installation						1.4771	

8.2 Reed Air Valve--Tooling Costs--Amortization Per Part

Part	Economic Volume	1 Year Recurring Tooling	3 Year Non-Recurring Tooling	12 Year Machinery & Equip	12 Year Launching Costs	40 Year Land & Buildings	Amortization Per Piece
		.0100	.0100	.0050	.0004		.0254
Manifold	2,000,000	20,000	60,000	120,000	10,000	-	
		.0200	.0100	.0100	.0008		.0408
Reed Valve	2,000,000	40,000	60,000	240,000	20,000	-	
		.0020	.0010	.0010	.0001		
Pipes	10,000,000	20,000	30,000	120,000	10,000	-	.0041
		.0050	.0040	.0100	.0012		
Fittings	10,000,000	50,000	120,000	1,200,000	150,000	-	.0202
		.0100	.0050	.0010	.0001		
Air Intake	2,000,000	20,000	30,000	24,000	2,000	-	.0161
Total		.0470	.0300	.0270	.0026		.1066
		.0500	.0250	.0250	.0025		
Engine Head	400,000	20,000	30,000	120,000	12,000	-	.1025
		.0250	.0250	.0075	.0008		
Vehicle Assembly	400,000	10,000	30,000	36,000	3,600	-	.0583
Total Vehicle							.2674

R&D estimates $900,000 for 3 years, or $.75 per vehicle.

8.3 Reed Air Valve

TOTAL MANUFACTURING COSTS

Part	Mat	Labor	Plant Over-Head	Plant Mfg Costs (MC)	Tooling		.20 MC Corp	.20 MC Corp Profit	Mfg/ Vendor Costs
					Exp.	Inv.			
Reed Valve	.880	.2390	.0956	1.2146	.0770	.0236	.2429	.2429	1.8070

8.4 Reed Air Valve

RETAIL PRICE EQUIVALENT
AT THE VEHICLE LEVEL

Part	Plant Vendor Costs	R&D	Tools & Equip	Corp. Alloc. .20 VC	Corp. Profit .20 VC	Dealer Markup .40 VC	Vehicle Retail Price Equivalent
Reed Valve	1.8070	.7500	-	.3614	.3614	.7228	4.0027
Engine Mod	.0875	-	.1025	.0175	.0175	.0350	.2600
Assembly	.1750	-	.0583	.0350	.0350	.0700	.3733
Total Vehicle Retail Price Equivalent							4.6360

8.5 Reed Air Valve

Cost Comparison to Aftermarket Selling Prices

Using the estimated costs, the aftermarket selling prices could vary between $8.95 and $17.80. No aftermarket data was available at this writing.

8.6 Reed Air Valve--Cost Methodology

The weight data was estimated using the sketches supplied by EPA. The material costs are compiled using the 1977 AMM mill prices.

The labor costs are estimates of production costs using today's technology and the assumed economies of scale. The tooling costs are estimates of the expendable tools and the machinery and equipment required to produce the components in a mass production environment.

The assembly costs and the engine modification costs were included in the costs at the vehicle level.

8.7 Reed Air Valve--Applications of the System

The applications of the Reed Air Valve systems are on 4-cylinder engines as a substitution of the fan air pump normally used on some 6-cylinder and 8-cylinder engines. We have assumed that this design is limited to 4-cylinder engines.

8.5 Reed Air Valve Cost Comparison to Aftermarket Selling Prices

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9.0 Exhaust gas recirculation is used, primarily, to lower peak combustion temperatures, and to control the formation of NOx. NOx emission at low temperatures is not severe; however, when the temperature exceeds about 2,500 °F, the production of NOx in the combustion chamber, is rapidly accelerated to high levels. Peak combustion temperatures can be reduced by retarding the spark, or, by introducing an inert gas such as exhaust gas to dilute the fuel mixture.

A small amount of exhaust gas is required to rapidly cool peak combustion temperatures. Therefore, the hole in the EGR valve is, necessarily, very small even when open to full capacity.

Chrysler, at one time, had one of the simplest exhaust recirculation systems. It had the floor jet under the carburetor. In this system, holes were drilled into the bottom of the intake manifold; then, calibrated jets were screwed into the holes. These holes penetrated the exhaust cross-over passage, allowing exhaust gases to enter the intake manifold constantly. The difficulty inherent in that system was exhaust gas recirculation at idle speeds. This was not only unnecessary for proper emissions control; but, unnecessarily caused rough idling engines. Most Chrysler engines now use a separate EGR valve, similar to those employed by all other manufacturers.

EGR valves are normally mounted on the intake manifold. When the valve opens, exhaust gases are allowed to pass usually from the crossover passage into the throat under the carburetor. The EGR valve is vacuum operated, by intake manifold vacuum on some engines, and by ported vacuum on others.

The ported vacuum systems are the simplest. At idle speeds, the port is avove the throttle blade, keeping the EGR valve closed. When the throttle is opened, vacuum acts on the port, and, the EGR valve opens. At full throttle, there is no intake manifold vacuum. This closes the EGR valve, giving the engine maximum power.

The EGR valve, on some vehicles, is operated by intake manifold vacuum. These valves use an amplifier in the circuit. The amplifier, which is controlled by venturi vacuum, operates the valve. A small hole in the carburetor venturi picks up vacuum, when the airflow through the carburetor is sufficient enough, and, sends the vacuum signal to the amplifier. The amplifier then opens, to allow manifold vacuum to act on the EGR valve. This amplifier system is used to obtain precise timing of EGR valve operations; additionally, exhaust recirculation does not commence, until engine speed is considerable above idle.

However, these systems, were found to be sensitive to outside air temperatures as well; and, were discontinued after March 15, 1973, as a result of the EPA order.

Ford uses a temperature control which resembles a PVS valve, except that it has two nozzles. This control shuts off the vacuum, to the EGR valve, at low temperatures.

When Chrysler stopped locating their air temperature sensor within the plenum chanber, they began using a valve, similar to Ford's, except mounted in the radiator. The Chrysler valve has two nozzles, with a hose connected to one, and a foam filter on the other. At low temperatures the valve opens, allowing air to enter. This weakens the vacuum, thus keeping the EGR valve closed.

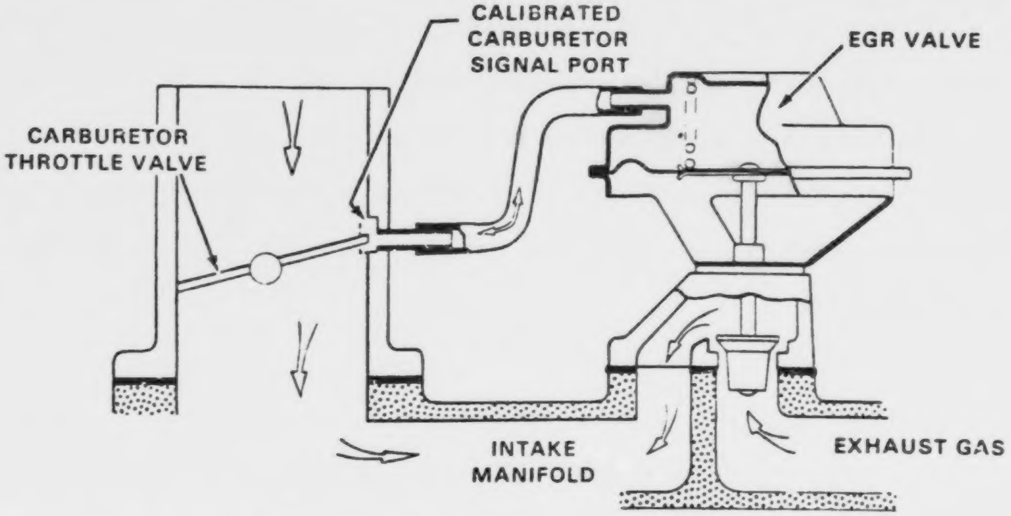
Buick has changed their EGR temperature regulation considerably. In 1972, they did not use a temperature control. In 1973 models, they used a temperature switch, located in the hose that shut off the vacuum to the EGR valve, at low temperatures. This switch was sensitive to engine compartment temperature, and was judged to be a defeat device by EPA. By March 15, 1973, Buick changed the switch to a coolant temperature switch, working with a vacuum solenoid. At low temperatures, this coolant switch caused the solenoid to shut off the vacuum to the EGR valve. In 1974, Buick eliminated the electric components in their system, and employed a straight coolant-vacuum switch, closing off the vacuum to the EGR valve, at low engine temperatures.

Cadillac used a switch in the hose similar to Buick's first switch. After March 15, 1973, they enclosed the switch in a housing; so that, it was more sensitive to engine temperature, rather than underhood temperature.

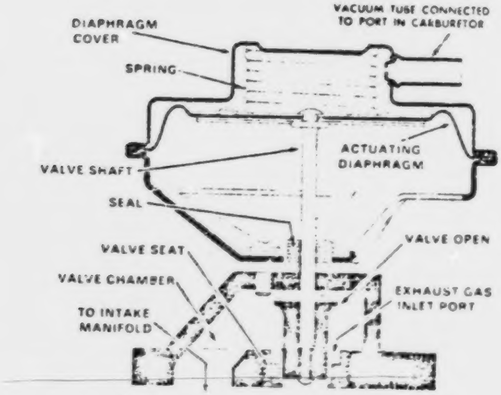
Chevrolet does not use temperature control for their EGR system. This is surprising, considering all other General Motors divisions do use a temperature control. Oldsmobile uses a mechanical temperature control valve in the hose to the EGR valve, similar to what Cadillac uses.

Pontiac probably has the most complicated system of all. Before March 15, 1973, the EGR system was tied in with the transmission control spark system. The two systems were hooked together, so that, when vacuum spark advance was allowed, there was no EGR. When EGR was allowed, there was no vacuum spark advance. This complicated system was eliminated on March 15, 1973; and, from then on, the EGR and the transmission control spark systems were separate.

9.0 EGR Systems

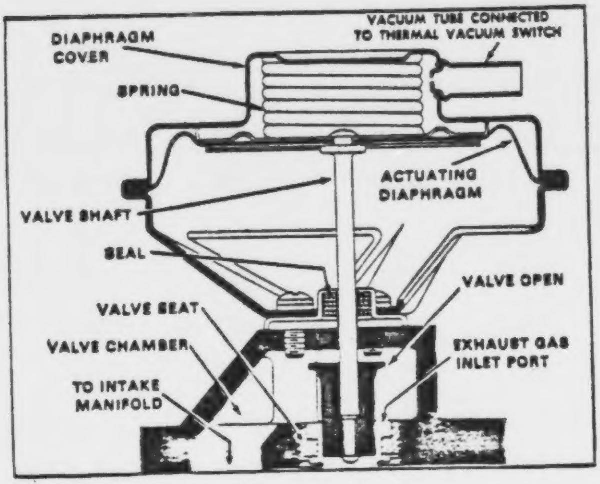

CALIBRATED
CARBURETOR
SIGNAL PORT
EGR VALVE
CARBURETOR
THROTTLE VALVE
INTAKE
MANIFOLD
EXHAUST GAS

Most cars use an EGR system with a valve and a ported vacuum signal, as shown here. Some cars use venturi vacuum with a separate amplifier to operate the valve

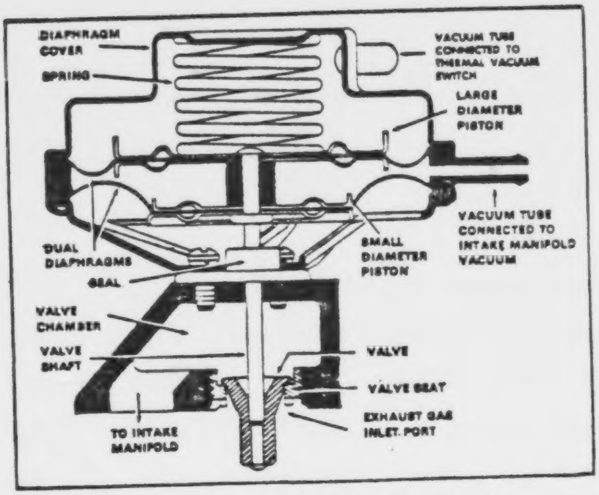

DIAPHRAGM
COVER
VACUUM TUBE CONNECTED
TO PORT IN CARBURETOR
SPRING
ACTUATING
DIAPHRAGM
VALVE SHAFT
SEAL
VALVE OPEN
VALVE SEAT
VALVE CHAMBER
EXHAUST GAS
INLET PORT
TO INTAKE
MANIFOLD

Cutaway of a typical General Motors EGR valve. The Chrysler and Ford valves are similar

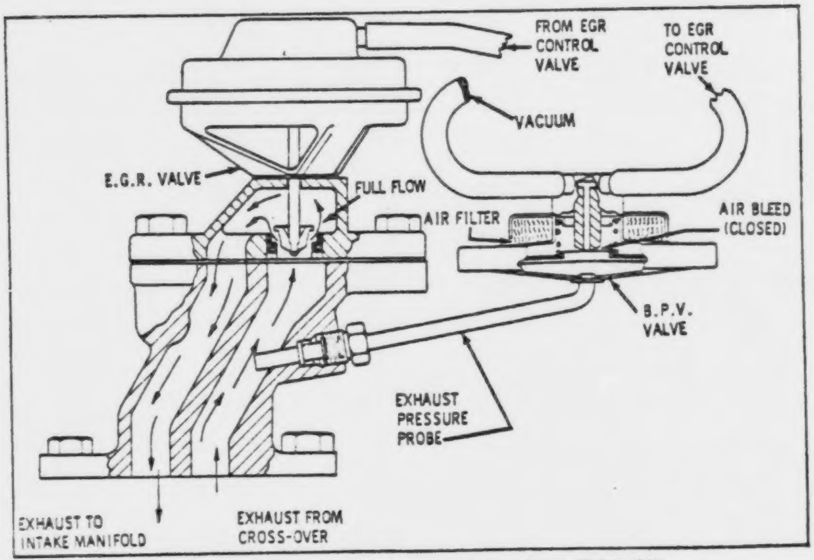
9.0 EGR Systems


VACUUM TUBE CONNECTED TO THERMAL VACUUM SWITCH
DIAPHRAGM COVER
SPRING
ACTUATING DIAPHRAGM
VALVE SHAFT
SEAL
VALVE OPEN
VALVE SEAT
VALVE CHAMBER
EXHAUST GAS INLET PORT
TO INTAKE MANIFOLD

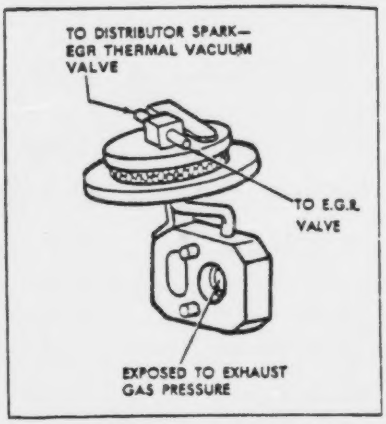
Single diaphragm EGR valve cross section


DIAPHRAGM COVER
SPRING
VACUUM TUBE CONNECTED TO THERMAL VACUUM SWITCH
LARGE DIAMETER PISTON
VACUUM TUBE CONNECTED TO INTAKE MANIFOLD VACUUM
DUAL DIAPHRAGMS
SEAL
SMALL DIAMETER PISTON
VALVE CHAMBER
VALVE SHAFT
VALVE
VALVE SEAT
EXHAUST GAS INLET. PORT
TO INTAKE MANIFOLD

Dual diaphragm EGR valve cross section


FROM EGR CONTROL VALVE
TO EGR CONTROL VALVE
VACUUM
E.G.R. VALVE
FULL FLOW
AIR FILTER
AIR BLEED (CLOSED)
B.P.V. VALVE
EXHAUST PRESSURE PROBE
EXHAUST TO INTAKE MANIFOLD
EXHAUST FROM CROSS-OVER

Exhaust back pressure transducer. Oldsmobile


TO DISTRIBUTOR SPARK—EGR THERMAL VACUUM VALVE
TO E.G.R. VALVE
EXPOSED TO EXHAUST GAS PRESSURE

Exhaust back pressure transducer. Pontiac

9.1 EGR Systems

BILL OF MATERIAL

MANUFACTURING COSTS

Part	Material	Weight	Mat Costs	Labor	Labor Overhead	Mfg Costs	Reference
EGR Valve Assy	Assem.	.880	–	.1250	.0500	.1750	17053105 or
Diaphragm Cover	Steel	.200	.0400	.1250	.0500	.2150	17052364
Diaphragm Spring	Steel	.100	.0200	.0625	.0250	.1075	$18.05
Large Dia. Piston	Steel	.090	.0180	.0312	.0125	.0617	
Diaphragms	Rubber	.050	.0200	.0156	.0062	.0418	
Small Dia. Piston	Steel	.090	.0180	.0312	.0125	.0617	
Vac. Tube Conn.	Steel	.100	.0200	.0156	.0062	.0418	
Seal	Steel Fibre	.050	.0200	.0156	.0062	.0418	
Valve Shaft	Steel	.100	.0200	.0312	.0125	.0637	
Valve	P Metal	.050	.0250	.0156	.0062	.0468	
Valve Seat	P Metal	.050	.0250	.0156	.0062	.0468	
			.2260	.4841	.1935	.9036	
EGR Vlve Adaptor	Steel	1.320	.2640	.0625	.0250	.3515	416499
Hoses	Rubber	.050	.0100	.0156	.0062	.0318	
Gaskets	Asb	.030	.0120	.0156	.0062	.0338	
			.2860	.0937	.0374	.4171	
Exhaust B.P. Transducer	Assem	.304	–	.1250	.0500	.1750	551083
Valve Cover	Steel	.064	.0128	.0156	.0062	.0346	
Filter	Steel	.060	.0120	.0156	.0062	.0338	
Spring	Steel	.060	.0120	.0156	.0062	.0338	
Piston	Steel	.020	.0040	.0078	.0031	.0149	
Probe	Steel	.100	.0200	.0625	.0250	.1075	
			.0608	.2421	.0967	.3996	
Total						1.7203	

9.1 EGR System

BILL OF MATERIAL

Part	Material	Weight	Mat Costs	Labor	Labor Overhead	Mfg Costs	Reference
Vehicle Assem	-	-	-	.2500	.1000	.3500	
Engine Mod.	-	-	-	.0625	.0250	.0875	
Total Vehicle Installation						2.1578	

9.2 EGR Systems--Tooling Costs--Amortization Per Part

Part	Economic Volume	1 Year Recurring Tooling	3 Year Non-Recurring Tooling	12 Year Machinery & Equip	12 Year Launching Costs	40 Year Land & Buildings	Amortization Per Piece
		.0200	.0200	.0100	.0010		.0510
EGR Valve Assy	1,000,000	20,000	60,000	120,000	12,000		
		.0050	.0050	.0025	.0002		.0127
Diaphragm Cover	2,000,000	10,000	30,000	60,000	6,000		
		.0020	.0020	.0010	.0001		.0051
Diaphragm Spring	5,000,000	10,000	30,000	60,000	6,000		
		.0025	.0050	.0015	.0002		.0092
Large Dia. Piston	2,000,000	5,000	30,000	36,000	3,600		
		.0050	.0040	.0010	.0001		.0101
Diaphragms	5,000,000	25,000	60,000	60,000	6,000		
		.0025	.0050	.0015	.0002		.0092
Small Dia. Piston	2,000,000	5,000	30,000	36,000	3,600		
		.0025	.0010	.0005	.0000		.0040
Vac. Tube Conn.	4,000,000	10,000	12,000	24,000	2,400		
		.0025	.0025	.0012	.0001		.0063
Seal	4,000,000	10,000	30,000	60,000	6,000		
		.0050	.0025	.0025	.0003		.0102
Valve Shaft	4,000,000	20,000	30,000	120,000	12,000		
		.0040	.0020	.0020	.0002		.0082
Valve	5,000,000	20,000	30,000	120,000	12,000		
		.0040	.0020	.0020	.0002		.0082
Valve Seat	5,000,000	20,000	30,000	120,000	12,000		
		.0550	.0510	.0257	.0026		.1343
		.0200	.0100	.0100	.0010		.0410
EGR Vlve Adaptor	1,000,000	20,000	30,000	120,000	12,000		
		.0040	.0017	.0025	.0002		.0084
Hoses	5,000,000	20,000	25,000	150,000	15,000		
		.0040	.0017	.0025	.0002		.0084
Gaskets	5,000,000	20,000	25,000	150,000	15,000		
							.0578

9.2 EGR Systems--Tooling Costs--Amortization Per Part (Continued)

Part	Economic Volume	1 Year Recurring Tooling	3 Year Non-Recurring Tooling	12 Year Machinery & Equip	12 Year Launching Costs	40 Year Land & Buildings	Amortization Per Piece
		.0200	.0100	.0050	.0005		.0355
Exh BP Transducer	1,000,000	20,000	30,000	60,000	6,000		.0127
		.0050	.0050	.0025	.0002		
Valve Cover	2,000,000	10,000	30,000	60,000	6,000		.0117
		.0050	.0050	.0015	.0002		
Filter	2,000,000	10,000	30,000	36,000	3,600		.0051
		.0020	.0020	.0010	.0001		
Spring	5,000,000	10,000	30,000	60,000	6,000		.0092
		.0025	.0050	.0015	.0002		
Piston	2,000,000	5,000	30,000	36,000	3,600		
							.0742
		.0333	.0667	.0167	.0017	-	.1183
Vehicle Assem	300,000	10,000	60,000	60,000	6,000		
		.0667	.0667	.0333	.0033	-	.1700
Engine Mod	300,000	20,000	60,000	120,000	12,000		
Total EGR System on Vehicle							.5546

R&D Estimate: 500,000 for 2 years, or $1.11 per vehicle for a 3-year payback.

9.3 EGR System

TOTAL MANUFACTURING COSTS

Part	Mat	Labor	Plant Over-Head	Plant Mfg Costs	Tooling		.20 MC Corp	.20 MC Corp Profit	Mfg/ Vendo Costs
					Exp.	Inv.			
EGR Valve	.2260	.4841	.1935	.9036	.1060	.0283	.1807	.1807	1.3995
EGR Valve Adaptor	.2640	.0625	.0250	.3515	.0300	.0110	.0703	.0703	.5331
Hoses & Gaskets	.0220	.0312	.0124	.0656	.0113	.0164	.0131	.0131	.1195
BP Transducer	.0608	.2421	.0967	.3996	.0615	.0127	.0799	.0799	.6335
Total Vehicle Mfg Costs									2.6857

9.4 EGR Systems

RETAIL PRICE EQUIVALENT
AT THE VEHICLE LEVEL

Part	Plant Vendor Costs	R&D	Tools & Equip	Corp. Alloc. .2 VC	Corp. Profit .2 VC	Dealer Markup .4 VC	Vehicle Retail Price Equivalent
EGR Valve	1.3995	1.1111	-	.2799	.2799	.5598	3.6302
EGR Adaptor	.5331	-	-	.1066	.1066	.2132	.9596
Hoses & Gaskets	.1195	-	-	.0239	.0239	.0478	.2151
BP Transducer	.6336	-	-	.1267	.1267	.2534	1.1405
Vehicle Assem	.3500	-	.1183	.0700	.0700	.1400	.7433
Engine Mod	.0875		.1700	.0175	.0175	.0350	.3275
Total Vehicle Price Equivalent							7.0212

9.5 EGR System

Cost Comparison to Aftermarket Selling Price

Using the aftermarket discount data and the aftermarket selling price, the following analysis is projected:

	Chilton Aftermarket Selling Price	Reference
EGR Valve	18.05	17052364
Discount 1/4	4.51	or
Discount 1/5	3.61	17053105

The estimated vendor costs are 1.3935 and the vehicle retail price equivalent is 3.6302. This figure includes $1.11 of R&D allocation.

9.6 EGR System--Cost Methodology

The weight data were obtained from the Oldsmobile computer printout. The material costs are compiled using the 1977 AMM mill prices.

The labor costs are estimates of production costs using today's technology and the assumed economies of scale. The overhead data are from a company communication. The tooling costs are estimates of expendable tools, fixtures, and dies, as well as estimates of equipment and machinery, to produce the components.

It was assumed that no new buildings were required to produce these parts.

The vehicle assembly costs and the engine changes were included in the costs at the vehicle level.

9.7 EGR System--Application of the Systems

Many domestic vehicles have engines equipped with an EGR valve similar to the design used in the estimate. The various applications to engines are numerous, due to the differences in locations in the 4, 6, and 8 cylinder engines. The hoses will vary due to the differences in locations.

10.0 Pelleted Oxidation Catalyst

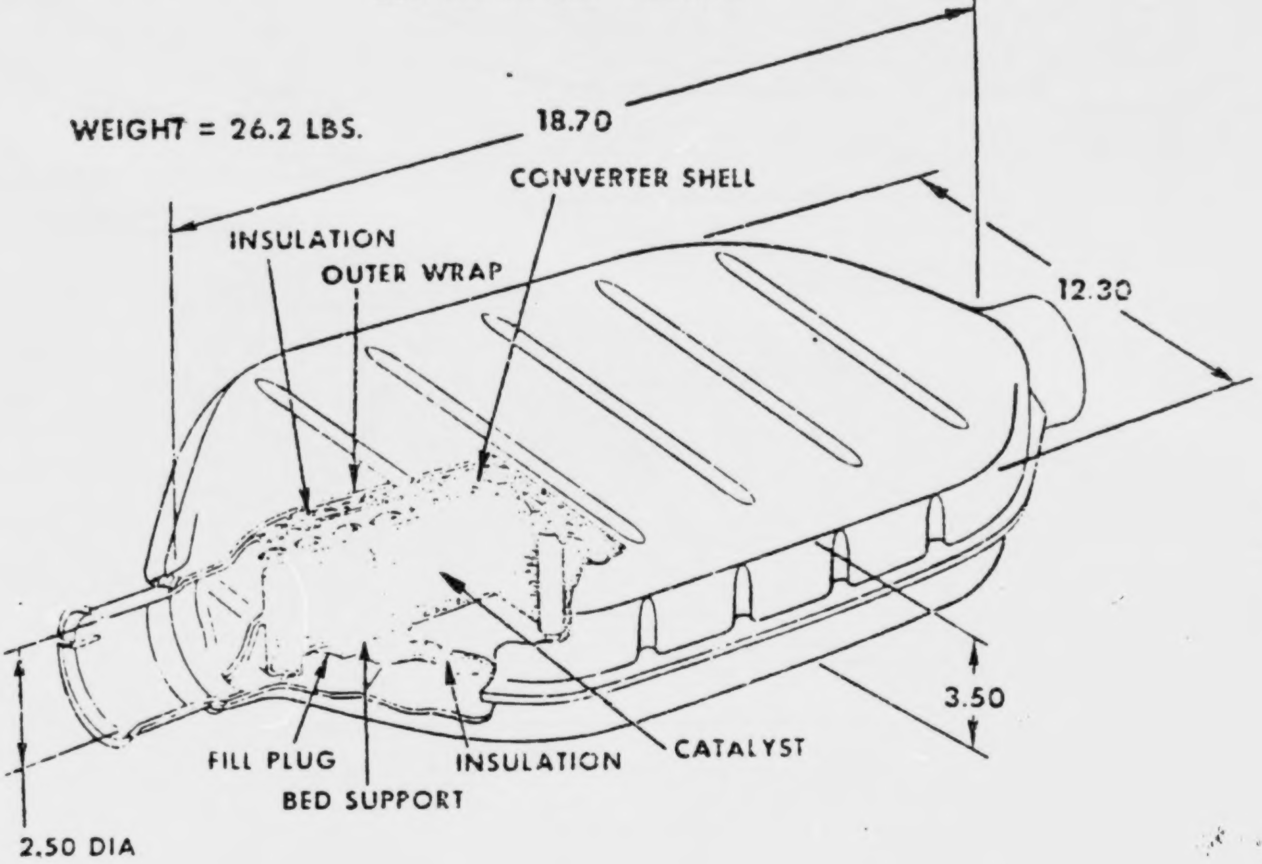
OXIDIZING CATALYTIC CONVERTER

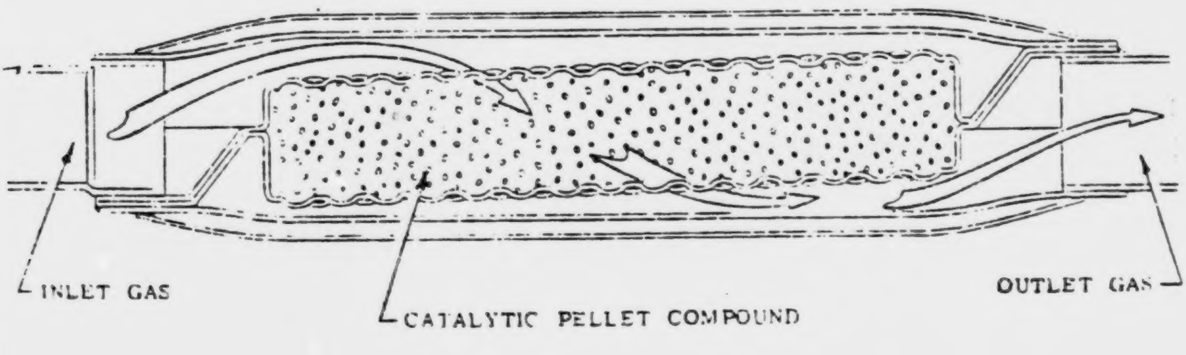
The oxidation of HC and CO in the exhaust stream can be accomplished at lower temperatures than the thermal reactor by using an appropriate catalyst. The catalyst is contained in a casing which directs the exhaust flow through the catalyst bed and protects the catalyst from mechanical damage. Compared with a thermal reactor, a catalytic converter can be placed further from the engine.

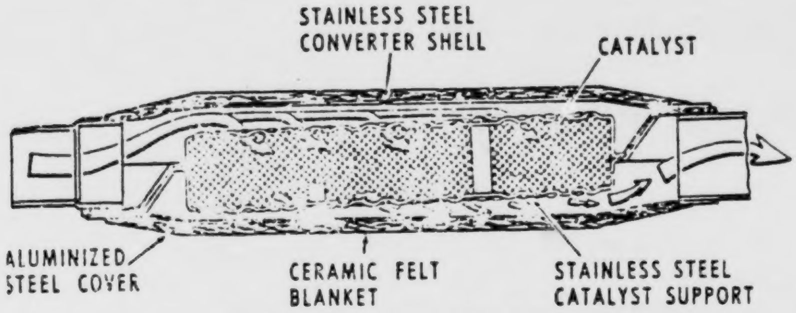
The catalyst consists of a thin layer of active material deposited on an inert support material. The catalytically active material is usually a noble metal such as a platinum or a combination of transition metal oxides. The support is usually alumina in the form of small pellets (as in pelleted catalysts) or a honeycomb monolith structure (as in monolithic catalysts). To obtain effective performance as rapidly as possible after engine start up, the density of the support material is kept as low as is practical. Catalytic converters require the use of fuels with very low levels of lead, phosphorus, and sulphur; small amounts of these contaminants lead to rapid deterioration of catalyst performance.

UNDERFLOOR CONVERTER - FULL FLOW

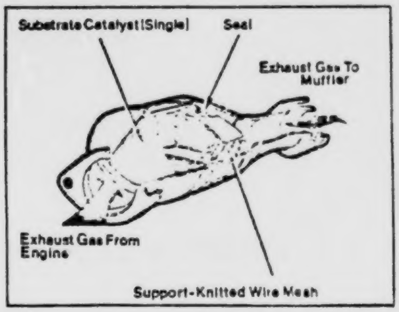
260 CU. IN. BED VOLUME


WEIGHT = 26.2 LBS.
18.70
CONVERTER SHELL
INSULATION
OUTER WRAP
12.30
3.50
FILL PLUG
INSULATION
CATALYST
BED SUPPORT
2.50 DIA

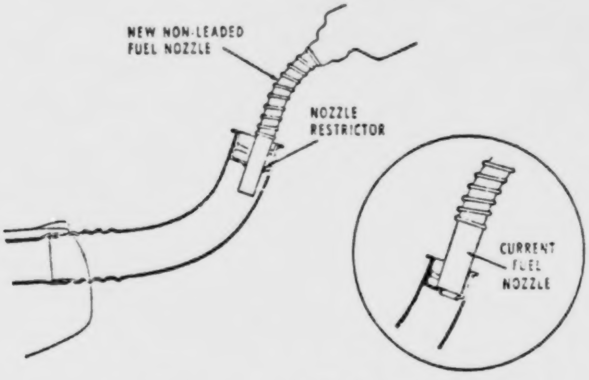

INLET GAS
CATALYTIC PELLET COMPOUND
OUTLET GAS


STAINLESS STEEL CONVERTER SHELL
CATALYST
ALUMINIZED STEEL COVER
CERAMIC FELT BLANKET
STAINLESS STEEL CATALYST SUPPORT

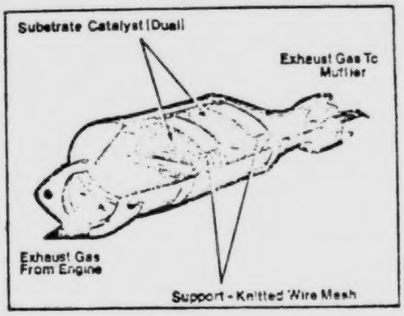
American Motors & General Motors catalytic converter


Substrate Catalyst (Single)
Seal
Exhaust Gas To Muffler
Exhaust Gas From Engine
Support-Knitted Wire Mesh

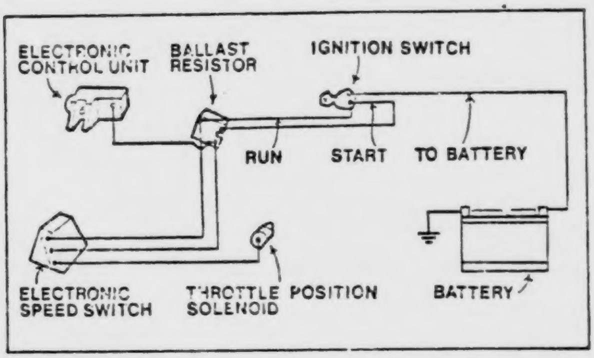
Ford catalytic converter
with single substrate catalyst


NEW NON-LEADED FUEL NOZZLE
NOZZLE RESTRICTOR
CURRENT FUEL NOZZLE

Fuel tank filler safety neck for all vehicles equipped
with catalytic converters (Typical)


Substrate Catalyst (Dual)
Exhaust Gas To Muffler
Exhaust Gas From Engine
Support - Knitted Wire Mesh

Ford catalytic converter
with dual substrate catalyst


ELECTRONIC CONTROL UNIT
BALLAST RESISTOR
IGNITION SWITCH
RUN
START
TO BATTERY
ELECTRONIC SPEED SWITCH
THROTTLE POSITION SOLENOID
BATTERY

Chrysler Corp. catalyst protection system for all vehicles
equipped with catalytic converters

10.1 Pelleted Oxidation--Catalyst

BILL OF MATERIAL
MANUFACTURING COSTS

Part	Material	Weight	Mat Costs	Labor	Labor Overhead	Mfg Costs	Reference
Converter Assem	Assem	26.20	-	1.1380	.4552	1.5932	110R 43M-23
Outer Wrap	409 SS	8.00	4.0000	.3400	.1360	4.4760	260CC
Shell	409 SS	4.00	2.0000	.3400	.1360	2.4760	
I/O Pipes	409 SS	2.50	1.2500	.1000	.0400	1.3900	
Bed Support	409 SS	3.77	1.8900	.3400	.1360	2.3660	
Insulation	Fibre Glass	1.50	1.5000	.0200	.0080	1.5280	
Pellets	Alumina PT	6.43	9.5450	.0200	.0080	9.5730	$1.50/lb
Total			20.1850	2.2980	.9192	23.4022	
Vehicle Assem	-	-	-	.1250	.0500	.1750	
Body Modification	-	-	-	.0625	.0250	.0875	
Total Vehicle				2.4855	.9942	23.6647	

10.2 Pelleted Oxidation Catalyst--Tooling Costs--Amortization Per Piece

Part	Economic Volume	1 Year Recurring Tooling	3 Year Non-Recurring Tooling	12 Year Machinery & Equip	12 Year Launching Costs	40 Year Land & Buildings	Amortization Per Piece	
		.1000	.2000	.3333	.0333	.2000	.8666	
Converter Assem	5,000,000	500,000	3,000,000	20,000,000	2,000,000	40,000,000		
		.1000	.2000	.3333	.0333		.6666	
Outer Wrap	5,000,000	500,000	3,000,000	20,000,000	2,000,000			
		.1000	.1000	.1667	.0167		.3833	
Shell	5,000,000	500,000	1,500,000	10,000,000	1,000,000			
		.0100	.0100	.0167	.0017		.0384	
I/O Pipes	10,000,000	100,000	300,000	2,000,000	200,000			
		.1000	.2000	.3333	.0333		.6666	
Bed Support	5,000,000	500,000	3,000,000	20,000,000	2,000,000			
		.0200	.0200	.0500	.0500		.0950	
Insulation	5,000,000	100,000	300,000	3,000,000	300,000			
		.0200	.0200	.0800	.0080		.1280	6 lbs/load
Pellets	5,000,000	100,000	300,000	5,000,000	500,000			
Total Converter							2.8444	
		.1000	.0300	.0300	.0030		.1630	
Vehicle Assem	300,000	30,000	30,000	120,000	12,000			
		.0500	.0500	.0100	.0010		.1110	
Body Modification	2,000,000	50,000	150,000	120,000	12,000			
Total Vehicle							3.1184	

R&D Estimates: $25,000,000 over 5 years, or about $1.600 per piece using a 3-year payback.

10.3 Pelleted Oxidation--Catalyst

BILL OF MATERIAL

MANUFACTURING COSTS

					Tooling				
Part	Mat	Labor	Plant Over-Head	Plant Mfg Costs	Exp.	Inv.	.20 MC Corp	.20 MC Corp Profit	Mfg/ Vendor Costs
Converter Assem	-	1.1380	.4552	1.5932	.3000	.5666	.3186	.3186	3.0970
Converter Can	10.640	1.1400	.4560	12.2360	.8600	.9898	2.4472	2.4472	18.9802
Pellets	9.5450	.0200	.0080	9.5730	.0400	.0880	1.9146	1.9146	12.5302
Total									34.6074

10.4 Pelleted Oxidation Catalyst

RETAIL PRICE EQUIVALENT
AT THE VEHICLE LEVEL

Part	Plant Vendor Costs	R&D	Tools & Equip	Corp. .2 MC Alloc.	Corp. .2 MC Profit	Dealer .4 MC Markup	Vehicle Retail Price Equivalent
Converter	34.6074	1.6000	-	6.9215	6.9215	12.8430	62.8934
Vehicle Assem	.1750	-	.1630	.0350	.0350	.0700	.4780
Body Mod	.0875	-	.1110	.0175	.0175	.0350	.2685
Total Vehicle Price Equivalent							63.6399

10.5 Pelleted Oxidation Catalyst Cost Comparison to Aftermarket Selling Price

Using the aftermarket selling price and discount data, the following analysis is projected:

	List Price	Reference
Converter	$161.25	8998210
1/4 Discount	40.31	
1/5 Discount	32.25	

The estimated vendor costs are $34.6074. The retail price equivalent for the converter on the vehicle is $63.6399.

10.6 Pelleted Oxidation Catalyst Cost Methodology

The weight data was obtained from the reference sketch. The pellet weight was also obtained from the sketch. The component weights are estimated by proportional methods.

The labor costs are estimates based on knowledge of the actual plant processes and manning. The economy of scale was established using the General Motors Milwaukee plant as the model.

The tooling and equipment costs are estimates using the General Motors plant as the reference. A new building was included in the cost computation.

The vehicle assembly costs and the body changes are added to the converter costs at the vehicle level.

10.7 Pelleted Oxidation Catalyst

Applications of the Systems

Since the pelleted catalyst is used on General Motors and American Motors cars, the variations are limited to two sizes with the possibility of a third size for 4-cylinder engines. These are:

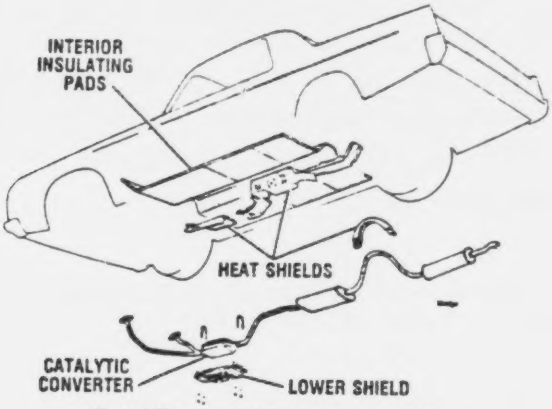
	Cost $
160 CID	21.2968
260 CID	34.6074
320 CID	42.5900

We selected the 260 CID size as the baseline. The costs of the other two sizes will be proportional to the CID.

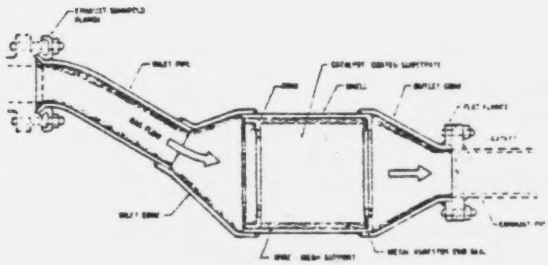
11.0 Monolithic Oxidizing Catalyst

The monolithic oxidizing catalyst converter consisting of noble metal wash coat on a ceramic or paper substrate mounted in an insulated metal container supported by a wire mesh screen. This construction is usually mounted close to the exhaust manifold ahead of the fire wall as an integral part of the exhaust pipe (either the Y-pipe or the straight pipe that connects to the muffler).

Its function is to convert the HC and CO gases to H_2O and CO_2 in the exhaust system.


INTERIOR INSULATING PADS
HEAT SHIELDS
CATALYTIC CONVERTER
LOWER SHIELD

Typical Chrysler catalytic converter mounting
(© Chrysler Corp)



Ford monolithic converter—cutaway view
(© Ford Motor Co)

OXIDIZING CATALYTIC CONVERTER
(Used on Chevrolet 250 cu. in. 6-Cylinder California Cars)

A 63 cu. in. manifold mounted oxidizing catalytic converter is used to help control hydrocarbon and carbon monoxide emissions in some L6 engine families.

A. Catalyst Supplier:

AC Spark Plug Division
1300 N. Dort Highway
Flint, MI 48556

Washcoat and Active Material Applied by:

Engelhard Mineral and Chemical Corp.
529 Delancy Street
Newark, New Jersey 07105

B. Number of converters used per vehicle: One

C. General Type: Oxidation

D. General Location: Attached to exhaust manifold

E. Substrate

1. Configuration: Monolith
2. Construction Technique: Extruded
3. Composition: Major phase - Cordierite
   Minor phase - Mullite
4. Supplier: AC Spark Plug
   1300 N. Dort Highway
   Flint, MI 48556

F. Washcoat: Alumina

G. Active Material:

1. Composition - Platinum and Palladium in 5.2 ratio
2. Total Loading - .029 troy oz.

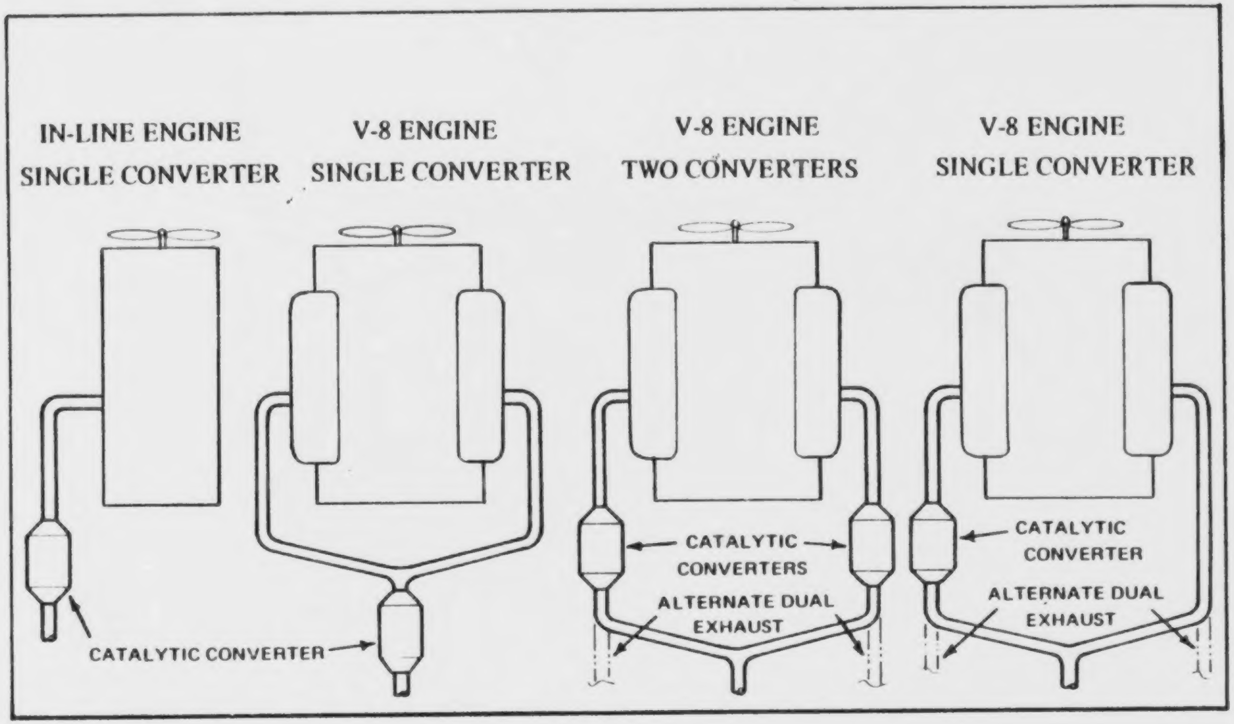
H. Container:

1-2 See Schematic
3 Volume - 2100 ml
4-6 The container is constructed of steel by forming and welding. The monolith is contained by metal mesh.
7 Canner: AC Spark Plug
8 (a) Insulation: None
(b) Shielding: None

I. Physical Description (of substrate)

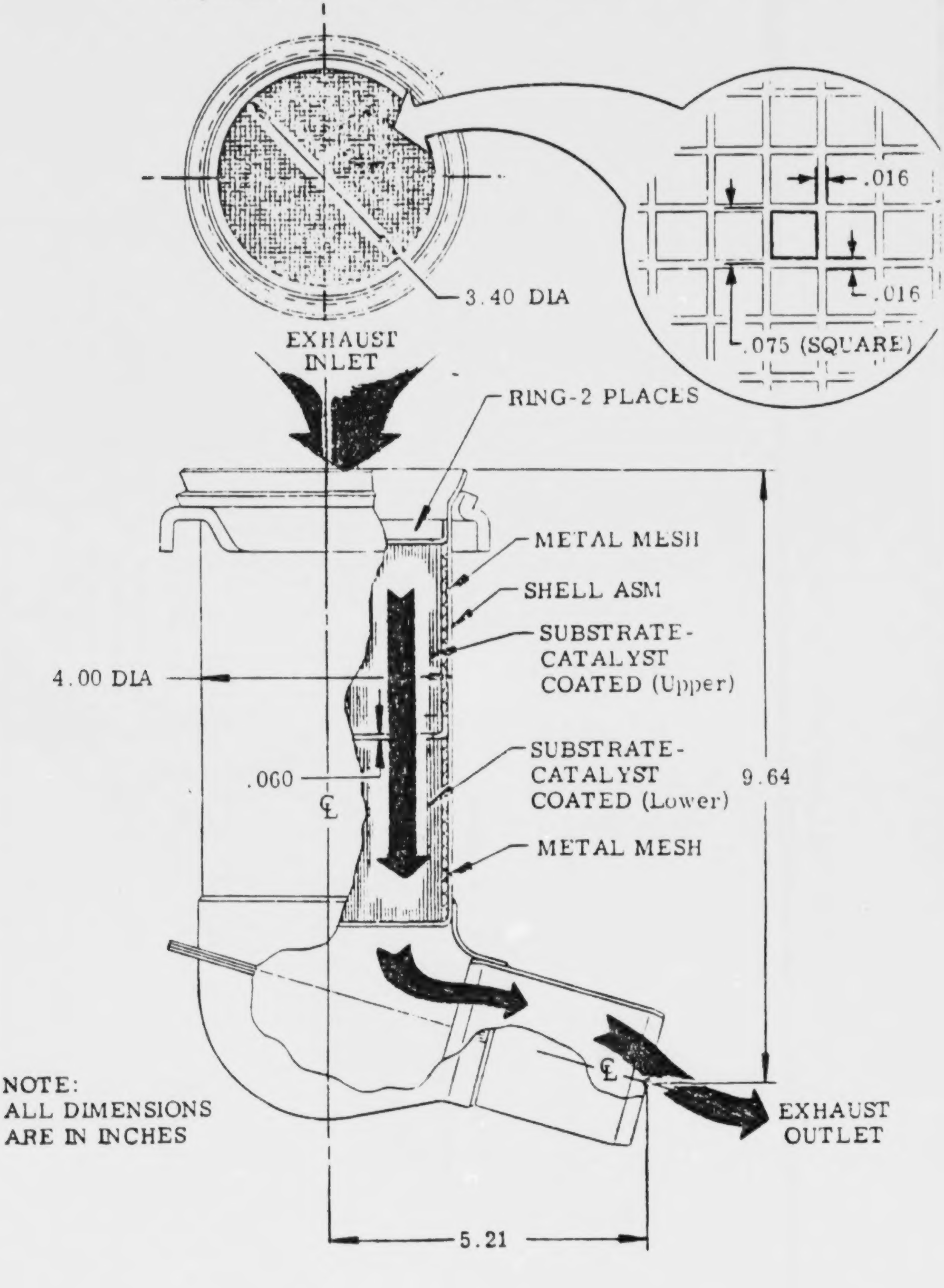
1. Dimensions: 2 pieces 3.66" diameter x 3" long
2. Weight: 1.9 lbs. (Modified to 1.3 per Corning Glass data)
3. Volume: 63 cu. in.
4. Total Surface Area (BET): 10,300M^2
5. Approximate Active Surface Area: 8,900M^2

TYPICAL INSTALLATIONS CATALYTIC CONVERTER


IN-LINE ENGINE
SINGLE CONVERTER
V-8 ENGINE
SINGLE CONVERTER
V-8 ENGINE
TWO CONVERTERS
V-8 ENGINE
SINGLE CONVERTER
CATALYTIC CONVERTER
CATALYTIC CONVERTERS
ALTERNATE DUAL EXHAUST
CATALYTIC CONVERTER
ALTERNATE DUAL EXHAUST

MANIFOLD CONVERTER

6 cylinder, 250 cu. in. Chevrolet (California)


.016
.016
.075 (SQUARE)
3.40 DIA
EXHAUST INLET
RING-2 PLACES
METAL MESH
SHELL ASM
SUBSTRATE-CATALYST COATED (Upper)
4.00 DIA
.060
℄
SUBSTRATE-CATALYST COATED (Lower)
9.64
METAL MESH
℄
EXHAUST OUTLET
5.21

NOTE:
ALL DIMENSIONS
ARE IN INCHES

11.1 Monolithic Oxidizing Catalyst

BILL OF MATERIAL

MANUFACTURING COSTS

Part	Material	Weight	Mat Costs	Labor	Labor Overhead	Mfg. Costs	Reference
Converter Assem	Assem	7.800	-	.2500	.1000	.3500	D5D Z5E212E
Shell	409 SS	2.000	.8000	.0625	.0250	.8875	179.05
Ring	409 SS	1.000	.4000	.0312	.0125	.4437	
Inlet Cone	409 SS	1.000	.4000	.0312	.0125	.4437	
Outlet Cone	409 SS	1.000	.4000	.0312	.0125	.4437	
Inlet Pipe	409 SS	1.000	.4000	.0312	.0125	.4437	
Flanges	409 SS	.250	.1000	.0156	.0062	.1218	
Mesh	409 SS	.150	.0600	.0156	.0062	.0818	
Hardware	Steel	.100	.0200	.0156	.0062	.0418	
Substrate	Ceramic	1.300	4.6800	.1250	.0500	4.8550	
Washcoat	AL_2O_3		.6000	.0625	.0250	.6875	
Platinum	Platin.	.02075 T. oz	3.4652	.0625	.0250	3.5527	
Paladium	Palad.	.0083 T. oz	.5731	.0312	.0125	.6168	
Total			11.8983	.7653	.3061	12.9697	
Vehicle Assem	-	-	-	.1250	.0500	.1750	
Body Modification	-	-	-	.1250	.0500	.1750	
Total Vehicle			11.8983	1.0153	.4061	13.3197	

11.2 Monolithic Oxidation Catalyst--Tooling Costs--Amortization Per Piece

Part	Economic Volume	1 Year Recurring Tooling	3 Year Non-Recurring Tooling	12 Year Machinery & Equip	12 Year Launching Costs	40 Year Land & Buildings	Amortization Per Piece
		.0300	.0300	.0150	.0015	.0500	.1265
Converter Assem	2,000,000	60,000	180,000	360,000	36,000	4,000,000	
		.0300	.0300	.0150	.0015		.0765
Shell	2,000,000	60,000	180,000	360,000	36,000		
		.0075	.0050	.0025	.0002		.0152
Ring	4,000,000	30,000	60,000	120,000	12,000		
		.0150	.0100	.0050	.0005		.0305
Inlet Cone	2,000,000	30,000	60,000	120,000	12,000		
		.0150	.0100	.0050	.0005		.0305
Outlet Cone	2,000,000	30,000	60,000	120,000	12,000		
		.0150	.0100	.0050	.0005		.0305
Inlet Pipe	2,000,000	30,000	60,000	120,000	12,000		
		.0050	,0038	.0012	.0001		.0101
Flanges	4,000,000	20,000	45,000	60,000	6,000		
		.0150	.0100	.0050	.0005		.0305
Mesh	2,000,000	30,000	60,000	120,000	12,000		
		.0010	.0010	.0020	.0002		.0042
Hardware	10,000,000	10,000	30,000	60,000	6,000		
							.3545
		.0300	.0300	.0250	.0025		.0875
Substrate	2,000,000	60,000	180,000	600,000	60,000		
		.0100	.0100	.0100	.0010		.0310
Washcoat	2,000,000	20,000	60,000	240,000	24,000		
		.0100	.0100	.0100	.0010		.0310
Platinum	2,000,000	20,000	60,000	240,000	24,000		
		.0100	.0100	.0100	.0010		.0310
Paladium	2,000,000	20,000	60,000	240,000	24,000		
							.1805
		.1000	.1000	.1000	.0100		.3100
Vehicle Assem	300,000	30,000	90,000	360,000	36,000		
		.0100	.0100	.0100	.0010		.0310
Body Modification	300,000	3,000	9,000	36,000	3,600		
Total							.8760

R&D--100 x 50M/year x 5 years = $25,000,000 - for 3=year payback/2M = 4.150/conversion.

11.3 Monolithic Oxidization Catalyst

TOTAL MANUFACTURING COSTS

Part	Mat	Labor	Plant Over-Head	Plant Mfg Costs	Tooling Exp.	Tooling Inv.	.20 MC Corp	.20 MC Corp Profit	Mfg/ Vendor Costs
Converter Assem	–	.2500	.1000	.3500	.0600	.0165	.0700	.0700	.5665
Converter Can	2.5800	.2341	.0936	2.9077	.1833	.0447	.5815	.5815	4.2989
Substrate	9.3183	.2812	.1125	9.7120	.1200	.0605	1.9424	1.9424	13.7773
									18.6432

11.4 Monolithic Oxidation Catalyst

RETAIL PRICE EQUIVALENT AT THE VEHICLE LEVEL

Part	Plant Vendor Costs	R&D	Tools & Equip	Corp .2 MC Alloc	Corp .2 MC Profit	Dealer .4 MC Markup	Vehicle Retail Price Equivalent
Converter Assem	.5665	4.1500	-	.1133	.1133	.2266	5.1697
Converter Can	4.2994	-	-	.8599	.8599	1.7198	7.7390
Substrate	13,7773	-	-	2.7555	2.7555	5.5110	24.7993
							37.7080
Vehicle Assem	.1750	-	.3100	.0350	.0350	.0700	.6250
Body Mod.	.1750	-	.0310	.0350	.0350	.0700	.3460
Total Vehicle Price Equivalent							38.6790

11.5 Monolithic Oxidation Catalyst--Cost Comparison to Aftermarket Selling Price

Using the aftermarket selling price and discount data, the following analysis is projected:

Converter Selling Price	$179.05
Discount 1/4	44.76
Discount 1/5	35.81

The estimated vendor costs are 18.6432. The retail price equivalent is 38.6790.

11.6 Monolithic Oxidation Catalyst--Cost Methodology

The weight data were obtained from the EPA and Chrysler data base. The material costs were computed using 1977 AMM mill prices.

The labor costs are estimates of production costs using today's technology and assumed economies of scale.

The tooling costs are estimates of expendable fixtures, dies, and molds. The machinery and equipment are separate estimates based on current costs of new equipment.

Some new building expenditures were included in the estimates since no prior capacity existed to produce the ceramic substrates.

Some modifications to the body structure were included in the estimates of labor and tooling.

11.7 Monolithic Oxidation Catalyst--Application of the Systems

Refer to the enclosed schematic which illustrates the locations by engine type.

12.0 Pelleted Reduction Catalyst (as a function of volume noble metal loading and composition)

(Same as 10 except for loading calculation.)

PELLETED CATALYTIC CONVERTERS

Reference sketch: Under-floor - full flow - 260 cubic inch BE.7 volume.

SIZE GRADATION CALCULATIONS

The configuration is regarded as two rectangular boxes, one centrally located within the other. The outer box is the housing and the inner is the catalyst.

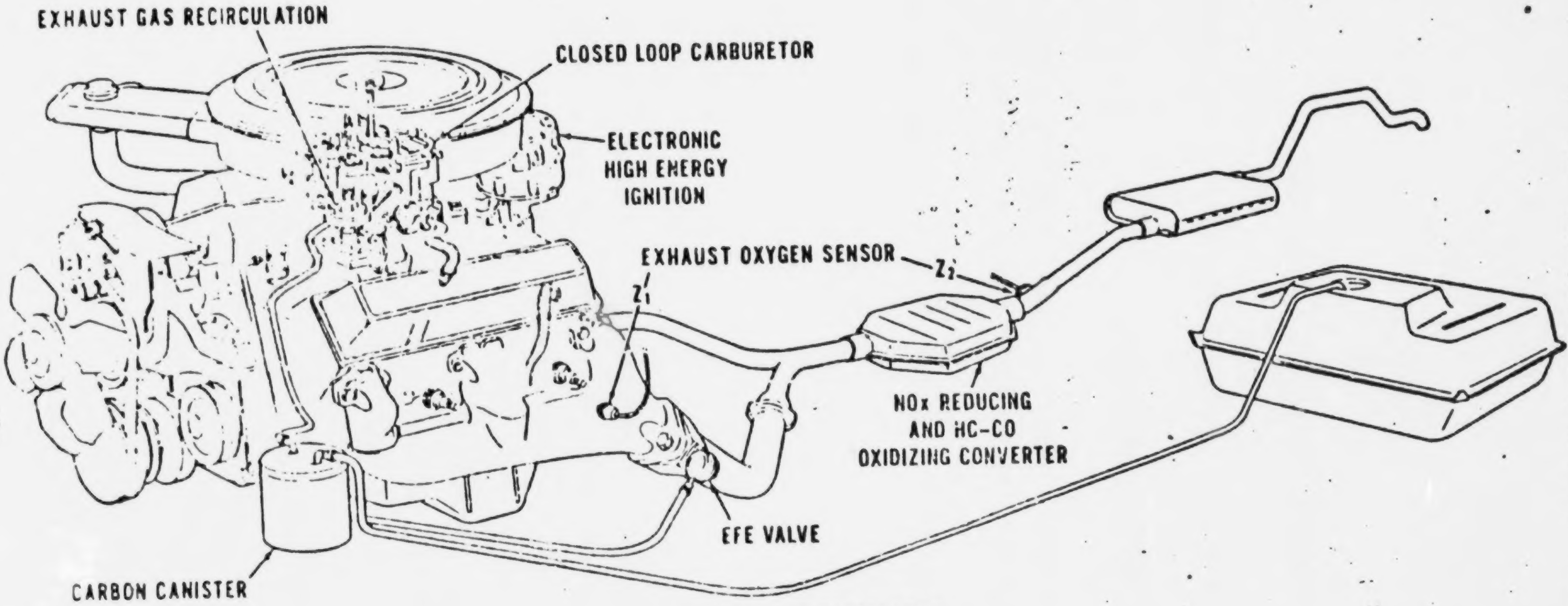
From the referenced sketch, these dimensions for the 260 cubic inch converter are used as basic:

	Height	Width	Length	Area	Volume
Housing	3.5	12.3	18.7	677	-
Catalyst	1.9	10.5	13.0	362	260

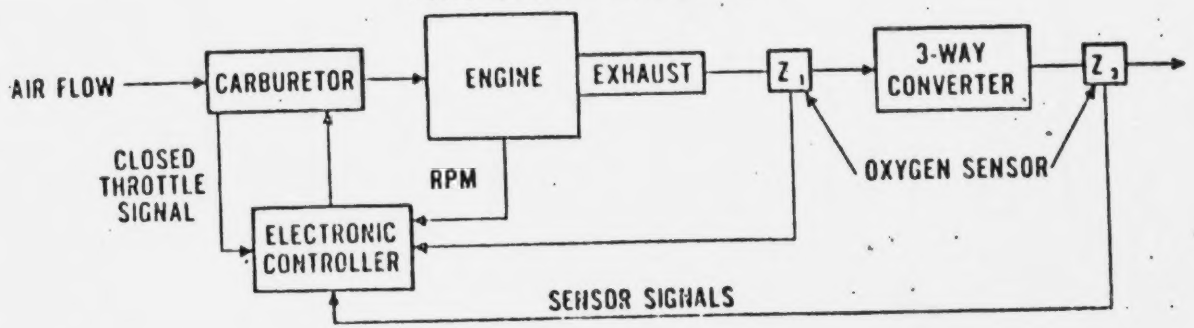
In graduating the dimensions to accommodate varying volumes, the catalyst height is held constant (to give maximum cross-flow contact and also to fit tail pipe). Length and width of catalyst are held in the same proportion, 13.0/10.5.

The housing length is constantly 5.7 greater than the catalyst length; the width differential is held at 1.8.

3-WAY CATALYST EMISSION CONTROL SYSTEM

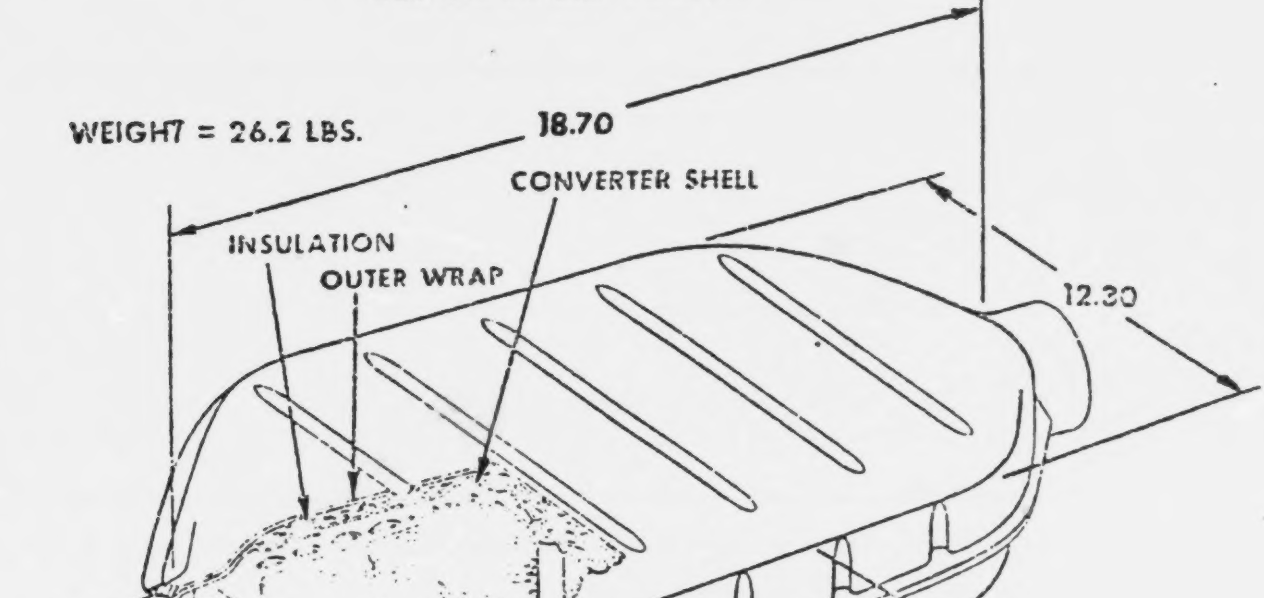

EXHAUST GAS RECIRCULATION
CLOSED LOOP CARBURETOR
ELECTRONIC HIGH ENERGY IGNITION
EXHAUST OXYGEN SENSOR
Z_1
Z_2
NOx REDUCING AND HC-CO OXIDIZING CONVERTER
EFE VALVE
CARBON CANISTER

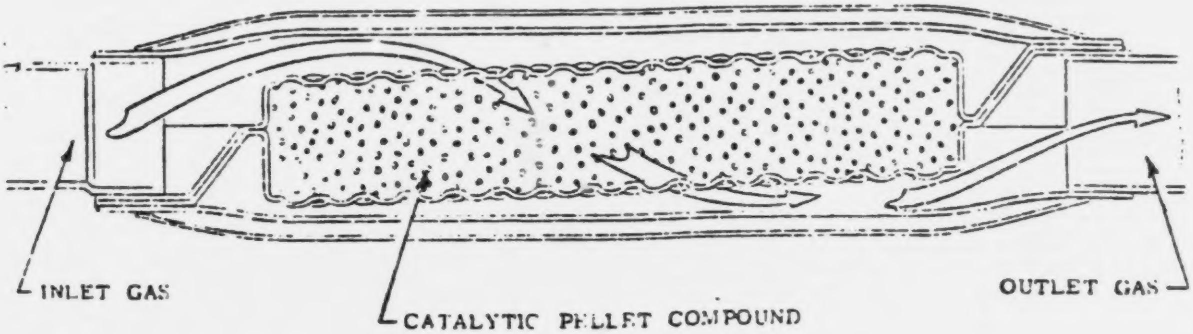
FUNCTIONAL SCHEMATIC


AIR FLOW
CARBURETOR
ENGINE
EXHAUST
Z_1
3-WAY CONVERTER
Z_2
OXYGEN SENSOR
CLOSED THROTTLE SIGNAL
RPM
ELECTRONIC CONTROLLER
SENSOR SIGNALS

UNDERFLOOR CONVERTER - FULL FLOW

260 CU. IN. BED VOLUME


WEIGH7 = 26.2 LBS.
18.70
CONVERTER SHELL
INSULATION
OUTER WRAP
12.30
3.50
CATALYST
FILL PLUG
INSULATION
BED SUPPORT
2.50 DIA


INLET GAS
CATALYTIC PELLET COMPOUND
OUTLET GAS

MANUFACTURING COST AND RETAIL PRICE EQUIVALENT ESTIMATIONS FOR PELLETED CATALYTIC CONVERTERS

Form B gives the equation relating noble metal composition, loading, and volume to plant manufacturing cost and retail price equivalent.

It applies to:

a. Pelleted oxidation catalysts.

b. Pelleted 3-way catalysts.

The calculations are based on extrapolation of the values given in the detailed estimate made on the 260 cubic inch under-floor oxidation catalyst.

The noble metal prices and the overall logic employed are the same as presented in the section on monolithic catalysts.

Work sheets are attached.

PELLETED STRUCTURAL PARTS--MANUFACTURING COST

Linear regression EQUATION

$Y = .03458\ x + 4.7975$

X	Y^1	Versus Calculated Values	Difference
50	6.526	6.318	.208
150	9.984	10.177	-.193
260	13.787	13.957	-.170
320	15.862	15.871	-.009
400	18.628	18.463	.165

Manufacturing Cost = .03458 (Volume) + 4.7975

PELLETED CATALYSTS--RETAIL PRICE EQUIVALENT

The following costs must be added to plant manufacturing cost to get the vendor cost.

Expense Tooling	$1.2000
Investment Tooling	1.6444
Vendor G & A	20% of Plant Manufacturing Cost
Vendor Profit	20% of Plant Manufacturing Cost

Vendor Cost = 1.4 (Manufacturing Cost) + $2.8444

To the vendor cost these must be added to get Retail Price Equivalent.

R & D	$1.60
Vehicle Assembly	.4780
Body Modification	.2685
Vehicle Corp. G & A	20% of Vendor Cost
Vehicle Corp. Profit	20% of Vendor Cost
Dealer Markup	40% of Vendor Cost

Retail Price Equivalent = 1.8 (Vendor Cost) + $2.3465
= 1.8 (1.4 (M.C.) + 2.8444) + $2.3465
= 2.52 (Plant Manufacturing Cost) + $7.4664

FORM B

CALCULATION SHEET FOR PLANT MANUFACTURING COST AND RETAIL PRICE EQUIVALENT PELLETED CATALYSTS

DATA:	LOADING (GM/FT^3)				VOLUME (IN.^{3})		TOTAL GRAMS
		÷	1728	×		=	

Pt/Pd Ratio =

Pt/Rh Ratio =

(Pt + Pd) Portion =

(Pt + Rh) Portion =

	Material	Pro-portions	Grams Req'd	Price per Gram	$ per Unit
CATALYTIC COMPONENTS	Platinum			5.369	
	Rhodium			14.628	
	Palladium			2.220	
	Renium			1.709	
	Ruthenium			2.009	
	Nickel			.005	
	Total Grams			--	--
	Labor & O.H.		x .12 =		
	Plant Manufacturing Cost				$
STRUCTURAL COMPONENTS	Plant Manufacturing Cost = $4.80 + (.0346 x volume)				$
	TOTAL PLANT MANUFACTURING COST				$

TOTAL PLANT MANUFACTURING COST $ × 2.52 + $7.466 = R.P.E. $

PELLETED CATALYSTS--DIMENSIONS

CATALYST							HOUSING				
Vol. ($in.^3$)	Hgt. (in.)	Wdth. (in.)	Lgth. (in.)	Area ($in.^2$)	Area Ratio	Vol. Ratio	Hgt. (in.)	Wdth. (in.)	Lgth (in.)	Area ($in.^2$)	Area Ratio
260	1.9	10.5	13.0	362	1.00	1.00	3.5	12.3	18.7	677	1.00
50	1.9	4.6	5.7	92	.25	.19	3.5	6.4	11.4	271	.40
150	1.9	8.0	9.9	226	.62	.58	3.5	9.8	15.6	484	.71
320	1.9	11.6	14.4	433	1.20	1.23	3.5	13.4	20.1	773	1.14
400	1.9	13.0	16.1	530	1.46	1.54	3.5	14.8	21.8	901	1.33

13.0 Monolithic Reduction Catalyst (as a function of volume, noble metal loading and composition)

(Same as 11.0 except for loading calculation.)

MANUFACTURING COST AND RETAIL PRICE EQUIVALENT ESTIMATIONS OF MONOLITHIC CATALYTIC CONVERTERS

1.0 Form A, attached, is, in effect, an equation relating noble metal composition, loading, and volume to manufacturing cost and retail price equivalent.

1.1 Form A applies to:

a. Monolithic oxidation catalysts.

b. Monolithic 3-way catalysts.

2.0 Derivation of the Form A equation for plant manufacturing costs.

2.1 Catalytic components--plant manufacturing costs.

2.1.1 Grams of each ingredient are precisely defined when proportions, volume, and loading are specified.

2.1.2 Prices are based on 1977 published quotations:

Platinum	$167./Troy oz.
Rhodium	$455./Troy oz.
Palladium	$ 69./Troy oz.
Rhenium	$ 53./Troy oz.
Ruthenium	$ 62./Troy oz.
Nickel	$2.23/lb.
Copper	/lb.

2.1.3 Labor and overhead, $.14/gram, is used as a constant; taken from the 63 cubic inch converter previously estimated in detail.

2.2 Structural components--plant manufacturing costs.

2.2.1 The detailed estimate for the 250 cubic inch 6-cylinder Chevrolet oxidizing catalytic converter (copy attached) is used as the base for extrapolating to other sizes.

2.2.2 To conform with the imposed maximums on diameter and length, 6" and 24" respectively, two diameters have been incorporated. For volumes up to 150 cubic inches, a 4" diameter shell is specified; above 150 cubic inches up to 400 cubic inches, a 5.4 inch diameter is specified.

Other variations of these dimensions would have minimal effect on the final costs.

2.2.3 The weights of the individual structural components of the basic 63 cubic inch unit were extrapolated on the geometrical ratios applicable to other volumes. These ratios were (where D = Diameter, L = Length, and V = Volume):

Shell - $(D \times L) + (\frac{D^2}{4})$
Rings - D ; (one per 5" length)
Inlet Cone - D
Outlet Cone - D
Inlet Pipe - D
Flanges - D
Mesh - $D \times L$
Hardware - D
Substrate - V
Wash Coat - V

2.2.4 Material costs per pound were maintained as used in the basic unit.

2.2.5 Labor costs for the components were computed on the generalized relationship that the rate of change of labor input is 60% that of the rate of change of weight, algebraically expressed:

$$\frac{L_2}{L_1} = 1 + 0.6 \left(\frac{W_2}{W_1} - 1 \right) = 0.4 + 0.6 \frac{W_2}{W_1}$$

2.2.6 Labor overhead held consistent at 40%.

2.2.7 Plant manufacturing cost is the sum of material cost, labor cost, and labor overhead.

2.2.8 Using the above guides, the plant manufacturing costs for seven sizes were calculated: (Work sheets attached) Results were:

Volume (In^3)	Plant Manufacturing Cost
10	3.3574
63 (Basic)	8.8002
100	12.9194
150	17.6189
200	22.9981
250	27.8292
300	32.9528
400	42.8742

2.2.9 Applying linear regression, a best-fit line was found.

Plant Manufacturing Cost = $2.52+ (.1013x Volume)

2.2.10 A graph, attached, of the data points and the best-fit line indicates the error band around the line.

Maximum error about $0.15

3.0 Derivation of the Form A equation for converting plant manufacturing to the retail price equivalent.

3.1 The equation is:

Retail Price Equivalent = (Plant Manufacturing Cost x $2.52) + $5.995

3.3.1 The remaining cost elements added to convert from plant manufacturing cost to retail price equivalent are:

Plant Manufacturing Cost	Plus
Expense Tooling	$.3640
Investment Tooling	$.1217
Vendor G & A	20% of Manufacturing Cost
Vendor Profit	20% of Manufacturing Cost

Equals Vendor Cost

V.C. = 1.4 (M.C.) + $.4857

Vendor Cost Plus	
R. & D.	$4.1500
Vehicle Assembly	$ .6250
Body Modification	$ .3460
Vehicle Corp G. & A.	20% of Vendor Cost
Vehicle Corp. Profit	20% of Vendor Cost
Dealer Markup	40% of Vendor Cost

Equals Retail Price Equivalent

R.P.E. = 1.8 (V.C.) = $5.121

= 1.8 (1.4 M.C. + .4857) + 5.121

= 2.52 (M.C.) + $5.9953

FORM A

CALCULATION SHEET FOR PLANT MANUFACTURING COST AND RETAIL PRICE EQUIVALENT OF MONOLITHIC OXIDATION & 3-WAY CATALYSTS

DATA:

LOADING (GM/FT^3)				VOLUME (IN.^{3})		TOTAL GRAMS
	÷	1728	×		=	

Pt/Pd Ratio = Pt/Rh Ratio =

(Pt+Pd Portion = (Pt+Rh Portion =

	Material	Pro-portions	Grams Req'd.	Price per Gram	$ per Unit
CATALYTIC COMPONENTS	Platinum			5.369	
	Rhodium			14.628	
	Palladium			2.220	
	Rhenium			1.709	
	Ruthenium			2.009	
	Nickel			.005	
	Total Grams			--	--
	Labor & O.H.		x .14 =		
	Plant Manufacturing Cost				$
STRUCTURAL COMPONENTS	Plant Manufacturing Cost = $2.52 + .1013 x volume				$

								R.P.E.
TOTAL PLANT MANUFACTURING COST	$	×	2.52	+	$5.995	=		$

14.0 Monolithic Start Catalyst

The start catalyst, or the warm-up catalyst, is designed to provide catalytic conversion during the first two minutes of the engine warm up. It is during this period (quick light off) that major emissions of HC + CO are created. The start catalyst is designed to provide conversion at 400° F or less while the main catalyst is still heating up. These catalysts were provided for California cars whose standard formula HC + CO + NOx was more stringent than the Federal standard.

14.1 Monolithic Start Catalyst

BILL OF MATERIAL

MANUFACTURING COSTS

Part	Mat	Weight	Mat Costs	Labor	Labor Over-Head	Mfg Costs	Reference
Converter Assem	Assem	3.610	-	.1250	.0500	.1750	AMC-California Car
Shell & Rings	409 SS	2.000	.8000	.0625	.0250	.8875	
Mesh	409 SS	.250	.1000	.0156	.0062	.1218	
I/O Cones	409 SS	.750	.3000	.0312	.0125	.3437	
Substrate	Ceramic	.530	1.9080	.0625	.0250	1.9355	
Platinum	Platin.	-	.7600	.0312	.0125	.8037	Pt/Pd = 2/1
Paladium	Palad.	-	.3800	.0156	.0062	.4018	Pt - \$167/oz = \$67 oz.
Washcoat	AL_2O_3	-	.3000	.0312	.0125	.3437	AL_2O_3
						5.0727	
Vehicle Assem	-	-	-	.1250	.0500	.1750	
Engine Mod	-	-	-	.1250	.0500	.1750	
Total						5.4227	

14.2 Monolithic Start Catalyst--Tooling Costs--Amortization Per Piece

Part	Economic Volume	1 Year Recurring Tooling	3 Year Non-Recurring Tooling	12 Year Machinery & Equip	12 Year Launching Costs	40 Year Land & Buildings	Amortization Per Piece
		.0300	.0300	.0100	.0010	-	.0710
Conv Assem	500,000	15,000	45,000	60,000	6,000		
		.0300	.0300	.0100	.0010		.0710
Shell	500,000	15,000	45,000	60,000	6,000		
		.0200	.0200	.0060	.0006		.0466
Mesh	500,000	10,000	30,000	36,000	3,600		
		.0150	.0100	.0036	.0003		.0289
I/O Cones	1,000,000	15,000	30,000	36,000	3,600		
							.2175
		.0300	.0300	.0300	.0030		.0930
Substrate	500,000	15,000	45,000	180,000	18,000		
		.0100	.0100	.0100	.0010		.0310
Washcoat	500,000	5,000	15,000	60,000	6,000		
		.0100	.0100	.0100	.0010		.0310
Platinum	500,000	5,000	15,000	60,000	6,000		
		.0100	.0100	.0100	.0010		.0310
Paladium	500,000	5,000	15,000	60,000	6,000		
							.1860
		.1000	.1000	.0100	.0010		.2110
Vehicle Assem	300,000	30,000	90,000	36,000	3,600		
		.0100	.0100	.0100	.0010		.0310
Engine Modification	300,000	30,000	9,000	36,000	3,600		
Total							.6455

R&D Estimate: 6 x 50K/Year = \$300,000/Year for 3 Years, or \$1.000/Car.

14.3 Monolithic Start Catalyst

TOTAL MANUFACTURING COSTS

Part	Mat	Labor	Plant Over-Head	Plant Mfg Costs	Tooling		.20 MC Corp Alloc	.20 MC Corp Profit	Mfg/ Vendor Costs
					Exp.	Inv.			
Converter Assem	-	.1250	.0500	.1750	.0600	.0110	.0350	.0350	.3160
Converter Can	1.2000	.1093	.0437	1.3530	.1250	.0215	.2706	.2706	2.0407
Substrate	3.3480	.1355	.0562	3.5397	.1200	.0660	.7079	.7079	5.141
Total									7.497

14.4 Monolithic Start Catalyst

RETAIL PRICE EQUIVALENT
AT THE VEHICLE LEVEL

Part	Plant Vendor Costs	R&D	Tools & Equip	Corp .2 MC Alloc	Corp .2 MC Profit	Dealer Markup .4 MC	Vehicle Retail Price Equivalent
Converter Assem	.3160	1.0000	-	.0632	.0632	.1264	1.5688
Converter Can	2.0407	-	-	.4081	.4081	.8162	3.6731
Substrate	5.1415	-	-	1.0283	1.0283	7.0566	9.2547
							14.4966
Vehicle Assem	.1750	-	.2110	.0350	.0350	.0700	.6250
Engine Mod	.1750	-	.0310	.0350	.0350	.0700	.3460
Total Price Equivalent							15.4676

14.5 Monolithic Start Catalyst--Cost Comparison to Aftermarket Selling Price

Using the aftermarket selling price and discount data, the following analysis is projected:

Start Catalyst (Estimated)	$72.00
Discount 1/4	18.00
Discount 1/5	14.40

The estimated vendor cost is 7.9084. The retail price equivalent on the vehicle is $15.4676.

14.6 Monolithic Start Catalyst--Cost Methodology

The weight data was obtained from the reference specification sheet for AMC installation.

The labor costs are estimates of production costs using today's technology and assumed economies of scale.

The tooling costs are estimates of expendable tools, fixtures, dies, and molds. The machinery and equipment are separate estimates based on current costs of new equipment.

No new building expenditures were included in the amortization.

Some costs of vehicle and engine modification were included.

14.7 Monolithic Start Catalyst

These installations are limited to AMC and some Chrysler California cars.

WARM-UP CATALYST DESCRIPTION*
AMC (California) used on 304 and 360 cu. in. engines

Catalyst Features, such as:

a) Catalyst supplier and address: Engelhard Industries Division
(Sole supplier)
430 Mountain Avenue
Murray Hill, New Jersey 07974

b) Number of catalysts used per vehicle: 1 for 6 cyl, 1 for V-8 Hornet/Pacer
2 for V-8 Matador

c) General Type: Oxidation

d) General Location: At exhaust manifold

e) Substrate:

(i) Configuration - Monolithic, segmented

(ii) Construction Technique - Extruded

(iii) Composition - Corderite

(iv) Supplier and Address: Corning Glass Works Division
(Sole supplier)
Corning, New York

f) Washcoat: Stabilized activated coating proprietory to manufacturer

g) Active Material:

(i) Composition of active constituents - Pt/Pd - 2/1

(ii) Total active material loading (gms. or Troy oz.) - 50 gm/ft.^{3}

h) Container:

(i) Configuration - Cylindrical

(ii) Dimensions - 3.87 dia. x 6.6 overall length

(iii) Volume - 48.8 In.^{3}

(iv) Materials used - 409 Stainless .054" min.

(v) Technique of containment & restraint - Compliant wire mesh
Mounting rings

(vi) Method of constructing container - Roll forming, draw forming
and welding

(vii) Canner: Maremont Corporation
(Sole supplier)
250 East Kehoe Boulevard
Carol Stream, Illinois 60187

(viii) Insulation and shielding (catalyst and/or vehicles) - None

i) Physical Description:

(i) Dimensions: 2 pieces, 3.66 dia. x 1.25; (3.31 EFF dia.)

(ii) Weight (lbs): Catalyst only, 0.61 lbs. (Modified to .53 lbs. per Corning Glass Data)

(iii) Volume: EFF Catalyst 21.5 In.^{3}, Total - 26.3 In.^{3}

(iv) Active surface area (BET): Proprietory to manufacturer

j) Catalyst Assembly Part Number: To be supplied

* American Motors does not perform any type of production performance test on the catalytic converter

WARM-UP CATALYST PART NUMBERS:

AMC (California) used on 304 and 360 cu. in. engines (Continued)

Vendor: Maremont Part #7-9102

Application	Part Number
Pacer (California)	#3229654
Hornet & Gremlin (California)	#3229837
Matador - V-8 (California)	#3230802 (Left) #3229867 (Right)

15.0 Monolithic Three-Way Catalyst (as a function of volume, noble metal loading and composition.)

(Same as 11.0 except for catalyst composition and loading.)

MANUFACTURING COST AND RETAIL PRICE EQUIVALENT ESTIMATIONS OF MONOLITHIC CATALYTIC CONVERTERS

Form A, attached, is, in effect, an equation relating noble metal composition, loading, and volume to manufacturing cost and retail price equivalent.

Form A applies to:

a. Monolithic oxidation catalysts.

b. Monolithic 3-way catalysts.

c. Monolithic reduction Catalysts.

d. Monolithic start catalysts.

Derivation of the Form A equation for plant manufacturing costs.

Catalytic components--plant manufacturing costs.

Grams of each ingredient are precisely defined when proportions, volume, and loading are specified.

Prices are based on 1977 published quotations:

Platinum (Pt)	$167./Troy oz.
Rhodium (Rh)	$455./Troy oz.
Palladium (Pd)	$ 69 /Troy oz.
Rhenium (Re)	$ 53./Troy oz.
Ruthenium (Ru)	$ 62./Troy oz.
Nickel (Ni)	$2.23/lb.
Copper (Cu)	$0.75/lb.

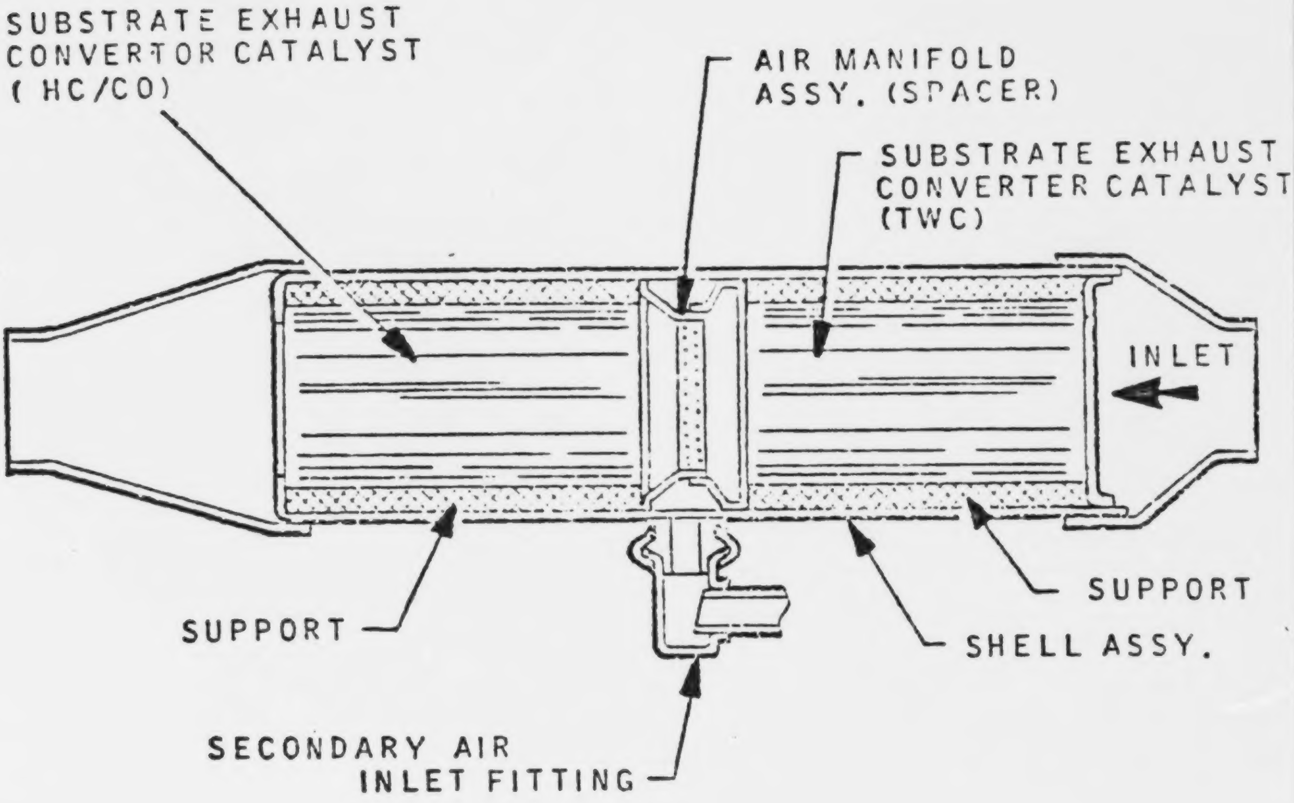
Labor and overhead, $.14/gram, is used as a constant; taken from the 63 cubic inch converter previously estimated in detail.

Structural components--plant manufacturing costs.

The detailed estimate for the 250 cubic inch 6-cylinder Chevrolet oxidizing catalytic converter (copy attached) is used as the base for extrapolating to other sizes.

To conform with the imposed maximums on diameter and length, 6" and 24" respectively, two diameters have been incorporated. For volumes up to 150 cubic inches, a 4" diameter shell is specified; above 150 cubic inches up to 400 cubic inches, a 5.4 inch diameter is specified.

TWC Catalytic Converter Assembly


SUBSTRATE EXHAUST
CONVERTOR CATALYST
(HC/CO)
AIR MANIFOLD
ASSY. (SPACER)
SUBSTRATE EXHAUST
CONVERTER CATALYST
(TWC)
INLET
SUPPORT
SUPPORT
SHELL ASSY.
SECONDARY AIR
INLET FITTING

FORM A

CALCULATION SHEET FOR PLANT MANUFACTURING COST AND RETAIL PRICE EQUIVALENT OF MONOLITHIC OXIDATION & 3-WAY CATALYSTS

DATA:	LOADING (GM/FT^3)				VOLUME (IN.^{3})		TOTAL GRAMS
		÷	1728	×		=	

Pt/Pd Ratio =

Pt/Rh Ratio =

(Pt+Pd) Portion =

(Pt+Rh) Portion =

	Material	Pro-portions	Grams Req'd.	Price per Gram	$ per Unit
CATALYTIC COMPONENTS	Platinum			5.369	
	Rhodium			14.628	
	Palladium			2.220	
	Rhenium			1.709	
	Ruthenium			2.009	
	Nickel			.005	
	Total Grams			--	--
	Labor & O.H.		x .14 =		
	Plant Manufacturing Cost				$
STRUCTURAL COMPONENTS	Plant Manufacturing Cost = $2.52 + .1013 x volume				$

							R.P.E.
TOTAL PLANT MANUFACTURING COST	$	×	2.52	+	$5.995	=	$

Other variations of these dimensions would have minimal effect on the final costs.

The weights of the individual structural components of the basic 63 cubic inch unit were extrapolated on the geometrical ratios applicable to other volumes. These ratios were (where D = Diameter, L = Length, and V = Volume):

Shell - (D x L) + $(\frac{D^2}{4})$
Rings - D ; (one per 5" length)
Inlet Cone - D
Outlet Cone - D
Inlet Pipe - D
Flanges - D
Mesh - D x L
Hardware - D
Substrate - V
Wash Coat - V

Material costs per pound were maintained as used in the basic unit.

Labor costs for the components were computed on the generalized relationship that the rate of change of labor input is 60% that of the rate of change of weight, algebraically expressed:

$$\frac{L_2}{L_1} = 1 + 0.6 \left(\frac{W_2}{W_1} - 1 \right) = 0.4 + 0.6 \frac{W_2}{W_1}$$

Labor overhead held consistent at 40%.

Plant manufacturing cost is the sum of material cost, labor cost, and labor overhead.

Using the above guides, the plant manufacturing costs for seven sizes were calculated: (Work sheets attached) Results were:

Volume (In^3)	Plant Manufacturing Cost
10	$ 2.5974
63 (Basic)	4.1202
100	4.9994
150	6.4589
200	8.1281
250	9.2492
300	10.6728
400	13.1742

Applying linear regression, a best-fit line was found.

Plant Manufacturing Cost = $2.38 + ($.0274 x Volume)

A graph, attached, of the data points and the best-fit line indicates the error band around the line.

Maximum error about $0.15

Derivation of the Form A equation for converting plant manufacturing to the Retail Price Equivalent.

The equation is:

Retail Price Equivalent = (Plant Manufacturing Cost x 2.52) + $5.995

The remaining cost elements added to convert from plant manufacturing cost to retail price equivalent are:

Plant Manufacturing Cost	Plus	Expense Tooling	$.3640	Equals	Vendor Cost
		Investment Tooling	$.1217		
		Vendor G&A	20% of Mfg. Cost		
		Vendor Profit	20% of Mfg. Cost		

Vendor Cost Equals 1.4 (P.M.C.) + $.4857

Vendor Cost	Plus	R&D	$4.1500	Equals	Retail Price Equivalant
		Vehicle Assembly	$0.6250		
		Body Modification	$0.3460		
		Vehicle Corp G&A	20% of Vendor Cost		
		Vehicle Corp Profit	20% of Vendor Cost		
		Dealer Markup	40% of Vendor Cost		

Retail Price Equivalent Equals 1.8 (V.C.) + $5.121
1.8 (1.4 M.C. + .4857) + $5.121
2.52 (M.C.) + $5.9953

16.0 Metallic Reduction Catalyst (as a function of volume, non-noble metal loading and composition)

(Same as 11.0 except for selection of non-noble metal loading and composition.)

METALLIC REDUCTION CATALYSTS

As far as the structural components are concerned, metallic reduction catalysts use the same configuration and, essentially, the same parts as the monolithic converters. The only deviation in figuring the cost is that the monolithic substrate honeycomb is eliminated.

Corrugated Nickel or Nickel-Copper foil .005" thick at a density of .02 pounds per cubic inch replaces the noble metals of the monolithic converters.

Form C incorporates the equation relating composition, volume, and costs.

The logic employed in deriving the equation is the same as described in the section on monolithic catalytic converters.

Work sheets are attached.

METALLIC REDUCTION CATALYST

Ni, Cu, Foil	-	Labor	=	$.06/lb.	=	$.00013/gm.
		O.H. 40%	=		=	.00005/gm.
		L. & O.H.				.00018/gm.
		Use				$.0002/gm.

Plant Mfg. Cost	Plus	Expense Tooling	$.3040	Equals	Vend
		Invest. Tooling	.0887		Cost
		Vendor G. & A.	20% Mfg. Cost		
		Vendor Profit	20% Mfg. Cost		

Vendor Cost = (1.4 x Plant Manufacturing Cost) + $.3927

Vendor Cost	Plus	R & D	$4.15	Equals	Retai
		Corporate G. & A.	20% Vendor Cost		Price
		Corporate Profit	20% Vendor Cost		Equi
		Dealer Markup	40% Vendor Cost		
		Vehicle Assembly	.6250		
		Body Modification	.3460		

RPE = (1.8 x Vendor Cost) + $5.121

= (2.52 x Plant Manufacturing Cost) + $5.8279

FORM C

CALCULATION SHEET FOR PLANT MANUFACTURING COST AND RETAIL PRICE EQUIVALENT METALLIC OXIDATION CATALYSTS

DATA:

LOADING (GM/FT^3)				VOLUME (IN.^{3})		TOTAL GRAMS
	÷	1728	×		=	

Ni/Cu Ratio =

	Material	Proportions	Grams Req'd.	Price per Gram	$ per Unit
CATALYTIC COMPONENTS	Nickel			.0049	
	Copper			.0017	
	Total Grams			--	--
	Labor & O.H.		× .0002 =		
	Plant Manufacturing Cost				$
STRUCTURAL COMPONENTS	Plant Manufacturing Cost = $2.28 + ($.0154 x volume)				$
	TOTAL PLANT MANUFACTURING COST				$

TOTAL PLANT MANUFACTURING COST $	×	2.52	+	$5.828	=	R.P.E.

METALLIC REDUCTION CATALYSTS

MANUFACTURING COST

Refer to Manufacturing Cost Calculation on structural components of 8 monolithic converters.

For each size, remove the costs and weights associated with the "ceramic substrat and the wash coat.

Resultants:

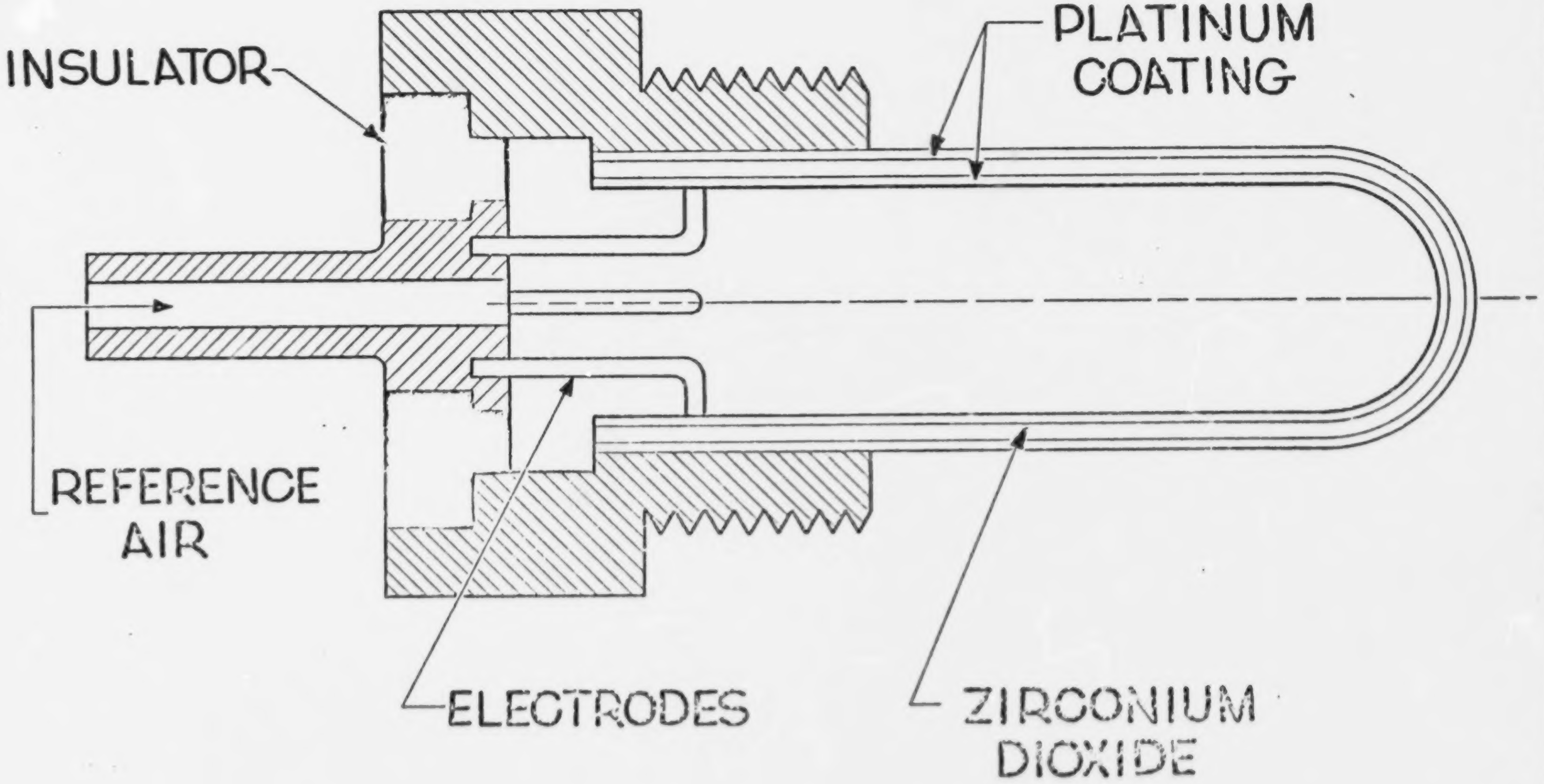
Vol.	Wgt.	Mat'l Cost	Labor	D.H.	Plant Mfg. Cost	Deviation F Best-Fit Li
10	4.65	$1.84	$ .3769	$.1507	$2.3676	$ .07
63	6.50	2.58	.4841	.1936	3.2577	0
100	7.40	2.94	.5398	.2159	3.6957	.11
150	9.17	3.65	.6423	.2569	4.5492	.03
200	11.47	4.56	.7595	.3038	5.6233	-.27
250	12.51	4.98	.8280	.3312	6.1392	-.03
300	14.21	5.66	.9270	.3707	6.9577	-.07
400	16.89	6.73	1.0925	.4370	8.2595	.16

Best-fit linear regression line:

Plant Manufacturing Cost = ($.0154 x Volume) + $2.2785

17.0 The oxygen sensor is an essential component of most three-way catalyst systems and is used to maintain a control of air-fuel ratio at or near stoichiometric. With most catalysts, this "window" for effective performance is exceedingly narrow, being the order of ± 0.1 A/F ratio units. The oxygen sensor provides a feedback loop to an electronic control unit.

OXYGEN SENSOR


PLATINUM COATING
INSULATOR
REFERENCE AIR
ELECTRODES
ZIRCONIUM DIOXIDE

Bendix Electronic Fuel Injection Division

17.1 Oxygen Sensor

BILL OF MATERIAL

Part	Material	Weight	Mat Costs	Labor	Labor Over-Head	Mfg Costs	Reference
Oxygen Sensor	Assem	.100	-	.0312	.0125	.0437	Bendix
Air Inlet	Brass	.020	.0200	.0156	.0062	.0418	
Insulator	Plastic	.015	.0150	.0078	.0031	.0259	
Nut. Body	Brass	.050	.0500	.0156	.0062	.0718	
Electrodes	Copper	.005	.0100	.0078	.0031	.0209	
Zirconium Dioxide	ZrO_3	.010	.0500	.0078	.0031	.0609	
Platinum	Platin	.000016	.0397	.0078	.0031	.0506	See RHF 2/77
Total			.1847	.0936	.0373		
Hose		.100	.100	-	-	.1000	
Electric	Wire & Insulator	.200	.200	-	-	.2000	
Total Oxygen						.3156	
Vehicle Assem		-	-	.0312	.0125	.0437	
Engine Modification		-	-	.0625	.0250	.0875	ECU Unit
Total Vehicle Installation						.7468	

17.2 Oxygen Sensor System--Tooling Costs--Amortization Per Part

Part	Economic Volume	1 Year Recurring Tooling	3 Year Non-Recurring Tooling	12 Year Machinery & Equip	12 Year Launching Costs	40 Year Land & Buildings	Amortization Per Piece
		.0100	.0050	.0020	.0002	-	.0172
Oxygen Sensor	5,000,000	50,000	75,000	120,000	12,000		
		.0040	.0040	.0020	.0002		.0102
Air Inlet	5,000,000	20,000	60,000	120,000	12,000		
		.0040	.0040	.0020	.0002		.0102
Insulator	5,000,000	20,000	60,000	120,000	12,000		
		.0100	.0100	.0040	.0004		.0244
Nut-Body	5,000,000	50,000	150,000	240,000	24,000		
		.0020	.0020	.0010	.0001		.0051
Electrodes	5,000,000	10,000	30,000	60,000	6,000		
		.0020	.0020	.0010	.0001		.0051
ZrO_3	5,000,000	10,000	30,000	60,000	6,000		
		.0100	.0100	.0040	.0004		.0244
Platinum	5,000,000	50,000	150,000	240,000	24,000		
Total		.0420	.0370	.0160	.0016		.0966
		.0040	.0017	.0025	.0002		.0084
Hose	5,000,000	20,000	25,000	150,000	15,000		
		.0040	.0017	.0025	.0002		.0084
Electric	5,000,000	20,000	25,000	150,000	15,000		
Total System							
		.0167	.0333	.0056	.0006		.0562
Vehicle Assem	300,000	5,000	30,000	20,000	2,000		
		.0333	.0222	.0083	.0006		.0644
Engine Modification	300,000	10,000	20,000	30,000	2,000		
Total Vehicle Systems							.2340

R&D Estimates: $600,000 for 3 years, or .67 per vehicle for engineering development.

17.3 Oxygen Sensor System

TOTAL MANUFACTURING COSTS

Part	Mat	Labor	Plant Over-Head	Plant Mfg Costs	Tooling Exp.	Tooling Inv.	.20 MC Corp	.20 MC Corp Profit	Mfg/ Vendor Costs
Oxygen Sensor	.1847	.0936	.0374	.3157	.0790	.0176	.0631	.0631	.5385
Hose	.100	-	-	.1000	.0057	.0027	.0200	.0200	.1484
Electric	.200	-	-	.2000	.0057	.0027	.0400	.0400	.2884
Total System									.9753

17.4 Oxygen Sensor System

RETAIL PRICE EQUIVALENT
AT THE VEHICLE LEVEL

Part	Plant Vendor Costs	R&D	Tools & Equip	Corp Alloc .20 VC	Corp Profit .20 VC	Dealer Markup .40 VC	Vehicle Retail Price Equivalent
Oxygen Sensor	.5385	.6667	-	.1077	.1077	.2154	1.6360
Hose	.1484	-	-	.0297	.0297	.0594	.2671
Electric	.2884	-	-	.0577	.0577	.1154	.5191
Vehicle Assem	.0437	-	.0562	.0087	.0087	.0175	.1349
Engine Mod	.0875	-	.0644	.0175	.0175	.0350	.2219
Total Vehicle Price Equivalent							2.7790

17.5 Oxygen Sensor System

Cost Comparison to Aftermarket Selling Prices

Using the aftermarket selling prices obtained from various company sources and aftermarket discount data, the following analysis is projected:

	Mathey Bishop M/B	Mercedes M/B
Oxygen Sensor	6.00	12.00
Discount 1/4	1.50	3.00
Discount 1/5	1.40	2.40

The estimated vendor costs are. 5385. The retail price equivalent for the valve on the vehicle is 1.6360.

17.6 Oxygen Sensor System

Cost Methodology

The weight data was obtained using a Chrysler weight table for a spark plug. The material costs are compiled using the 1977 AMM mill prices.

The labor costs are estimates of production costs using today's technology and the assumed economies of scale. The platinum loading was obtained from EPA (Mr. Field) computations. The tooling costs are estimates of the expendable tools and the machinery and equipment required to produce the components.

The assembly costs and the engine changes were included in the costs at the vehicle level.

17.7 Oxygen Sensor System

Applications of the O_2 System

The Bendix and Bosch systems are similar designs. We have assumed that this sensor will not vary by engine size although it is possible that more than one sensor could be used in an electronically controlled three-way catalyst system.

18.0 Electronic Fuel Metering System

(Bosch, Bendix, and Chrysler System)

The EFI-L (Electronically-Controlled Fuel Injection System, Air-Flow Sensitive), is an intermittently operating system, with, low-pressure injection of fuel into the intake manifold. In this system, the quantity of air drawn in by the engine is measured directly, and is used as the main control parameter for the quantity of fuel required. The fuel is metered by solenoid-operated injection valves. These valves are under constant fuel pressure, and, their optimum opening period, which is proportional to the amount of fuel injected, is determined for every operating function of the engine by the electronic control unit on the basis of information received from various electrical sensors.

The electronic fuel injection systems for gasoline piston engines are primarily a development of European technology, although the Bendix Corporation in the U.S.A. has a cross licensing arrangement with Bosch in Germany for technology exchange. No mass production manufacturing facility exists in the U.S.A. to produce electronic fuel injection and electronic emission control subsystems for gasoline piston engines.

Fuel Pumps (39 PSIG)--an electrically-driven motor coupled to a constant-flow rotary pump.
Fuel Filter--a close tolerance filter that eliminates particles that would clog the fuel nozzles.

Fuel intake manifold with provision for mounting the fuel rail.

Fuel nozzles--a precision solenoid operated by the electronic control unit.

Throttle body--the basic air control unit that includes a throttle sensor and a cold-start air control.

Speed sensor unit--the magnet assembly equipped with a reed switch assembly for sensing the engine R.P.M.

Electronic control unit and subsystem--this system provides the control signals and the feedback response from water and air sensors pressure sensors, and a fuel pressure regulator. When combined with most three-way catalyst systems, the ECU includes the capability of receiving feedback from an oxygen sensor and adjusts the air-fuel ratio accordingly.

Oxygen-sensor--the platinum-coated ceramic sensor located in the exhaust stream. This is normally included only with three-way catalyst systems.

The EFI system coupled with a 3-way catalyst system is currently being installed in some European vehicles sold in the U.S.A. most of which are sold in the State of California.

Currently, these units are manufactured and bought in relatively small annual quantities; and, consequently, unit costs are higher than they would be if quantities were increased by several magnitudes. In order to arrive at a logical and consistent method, for realistically estimating future costs at higher purchase quantities, a learning curve methodology has been employed.

Estimates of prices on 5,000; 200,000; and 500,000 lot sizes were solicited from U.S.A. and European sources. (These are shown in the first three columns of Table 1.) Analysis of these figures indicates a learning curve of 91.4%, with individual items deviating, but not significantly, in the overall. (A 91.4% curve means an 8.6% decrease in unit cost for each doubling of the quantity.)

The last two columns in Table 1 are mathematical extrapolations of the 500,000 price by .014 and .742 respectively to estimate prices for 1,000,000 and 5,000,000 units.

The plan for production of electronic fuel injection systems at various volumes was proposed as:

Year	Volume	Production Plan
1975	5,000	Purchase all the components from known U.S.A. and European sources.
1976/77	200,000	Start manufacturing nozzles, throttle devices, fuel pumps, and ECU units. Purchase mass production loading.
1978/79	500,000	Redesign the ECU using integrated circuits and combine some of the e external serve functions into the ECU. Provide for mass production facilities of the major components. Include the major valves as manufactured items.
1979/80	1,000,000/5,000,000	Develop a new cost reduction design and include the balance of the items in the manufacturing program. Tool up the final mass production facilities for all components.

The total investment for such a facility to produce 5,000,000 units per year would be $55,000,000, which includes launching costs and equipment costs. Over $11,300,000 would be expended for tooling the nozzles.

Table 1 - OEM COSTS--8-CYLINDER SYSTEM

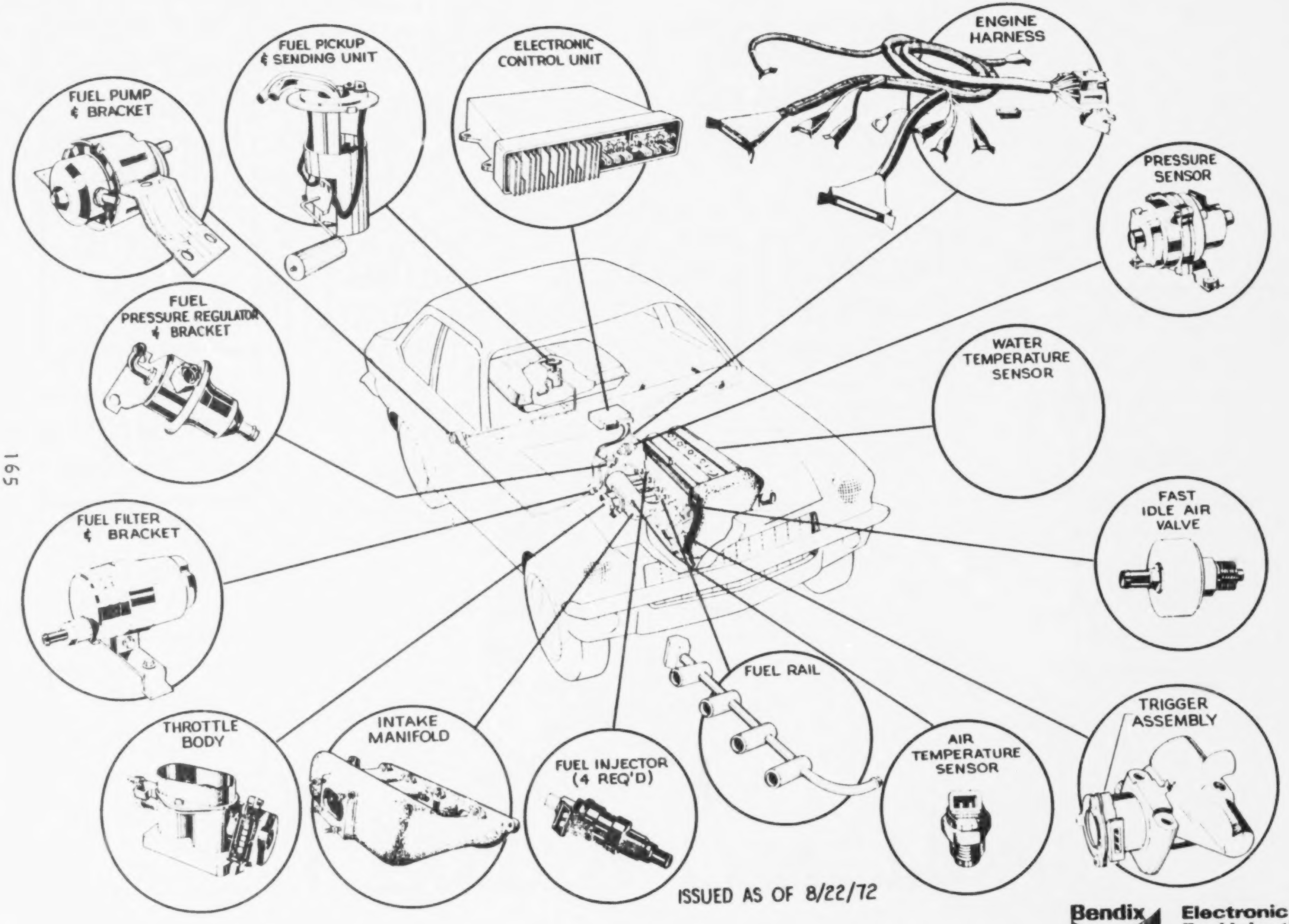
	Industry Estimates			Projected Estimates	
Quantity	5 K	200 K	500 K	1,000 K	5,000 K
Injectors	$ 56.00	$ 40.00	$ 32.00	$ 29.25	$ 23.74
O_2 Sensor *	6.00	4.50	2.36	2.16	1.75
ECU	75.00	45.00	45.00	41.13	33.39
Air Temperature	1.75	1.75	1.25	1.14	.93
H_2O Temperature	1.75	1.75	1.25	1.14	.93
Throttle Switch	3.00	3.00	2.30	2.10	1.71
Fuel Pump Assembly	15.00	15.00	12.00	10.97	8.90
Fuel Pressure Regulator	3.00	2.90	2.57	2.35	1.91
Fast Idle Valve	5.00	3.51	2.00	1.83	1.48
Throttle Body	10.00	8.78	5.00	4.57	3.71
Air Solenoid Valve	4.00	3.25	2.00	1.83	1.50
Fuel Filter	3.50	2.00	1.00	.91	.74
Fuel Rail	8.50	6.00	5.00	4.57	3.71
Speed Sensor	1.50	1.00	.75	.69	.56
Intake Manifold					
Wiring Harness	25.20	10.00	5.00	4.57	3.71
	$219.20	$148.44	$119.48	$109.21	$ 88.67

*Normally used with three-way catalyst systems only.

The sticker price contribution for feedback controlled EFI systems installed in various size vehicles and engines at a production volume of 5,000,000 units would be:

Vehicle	Cyl. CID	Mfg. Cost	Markup	Sticker Price
Subcompact	4 - 140	$76.80	1.8	$138.00
Compact	6 - 250	82.97	2.0	166.00
Standard	8 - 350	88.67	2.2	195.00

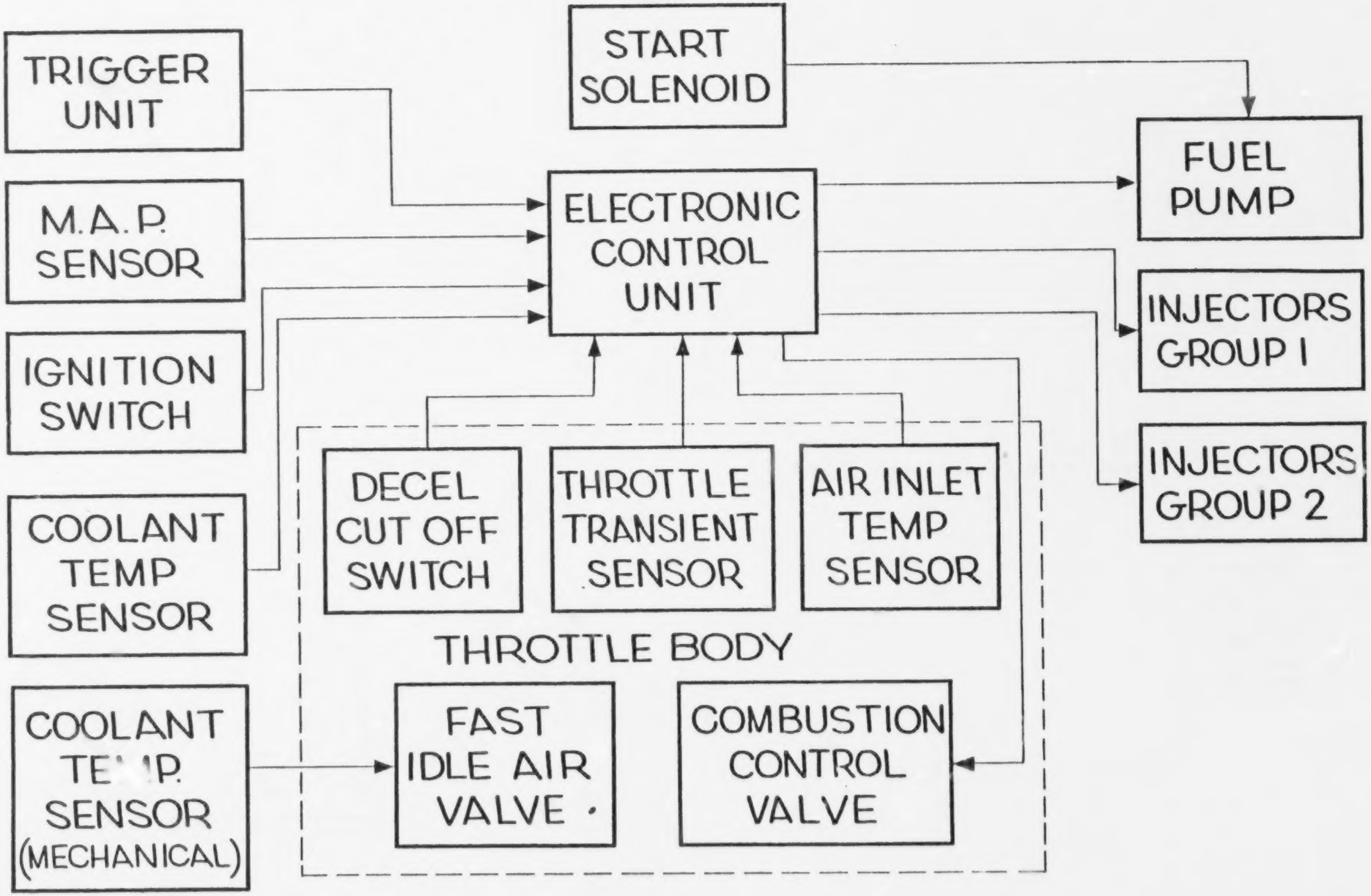
When making comparisons to feedback controlled carbureted systems for these same engines, the control valves, sensors, and feedback controls must be included. Also, a more sophisticated carburetor, valued at $18 to $24 manufacturing costs, has to be considered. The author has created the delta costs to achieve several levels of emissions. When making comparisons of feedback controlled EFI and carbureted systems, to achieve the same levels of emissions, the cost deltas are not significantly different at the vehicle sticker price level.


ENGINE HARNESS
FUEL PICKUP & SENDING UNIT
ELECTRONIC CONTROL UNIT
FUEL PUMP & BRACKET
PRESSURE SENSOR
FUEL PRESSURE REGULATOR & BRACKET
WATER TEMPERATURE SENSOR
FUEL FILTER & BRACKET
FAST IDLE AIR VALVE
FUEL RAIL
TRIGGER ASSEMBLY
THROTTLE BODY
INTAKE MANIFOLD
FUEL INJECTOR (4 REQ'D)
AIR TEMPERATURE SENSOR

ISSUED AS OF 8/22/72

Bendix Electronic Fuel Injection Division

EFI SYSTEM FUNCTIONS



TRIGGER UNIT

M.A.P. SENSOR

IGNITION SWITCH

COOLANT TEMP SENSOR

COOLANT TEMP. SENSOR (MECHANICAL)

START SOLENOID

ELECTRONIC CONTROL UNIT

FUEL PUMP

INJECTORS GROUP I

INJECTORS GROUP 2

DECEL CUT OFF SWITCH

THROTTLE TRANSIENT SENSOR

AIR INLET TEMP SENSOR

THROTTLE BODY

FAST IDLE AIR VALVE

COMBUSTION CONTROL VALVE

18.0.1 Electronic Control Unit

The Electronic Control Unit is the heart of the EFI system. Its function is to deliver fuel to the engine at a rate which is a function of continuously measured engine input and output parameters. The current production model ECU also provides fuel pump power control, engine start auziliary air control, and exhaust gas recirculation (EGR) on/off control.

The circuit design architecture of the Electronic Control Unit, relies on several production technologies. Four custom bipolar integrated circuits implement the core control law function that is common to all ECU calibrations. These circuits are contained on a ceramic thick-film substrate module. Unique circuit functions are implemented using standard bipolar integrated circuits and discrete components. Thick-film laser trimmed passive resistor networks are incorporated to realize base calibration, and each individual production unit is final trimmed to meet performance specifications. Additional components include the intake manifold pressure sensor, two power relays, and a custom hard mounted connector. All components are mounted on two printed circuit boards, which are conformal coated for environmental protection.

The Electronic Control Unit is installed in the passenger compartment behind the dash panel. It is designed to function at a maximum temperature of 185°F (85°C). In the current production model, no attempt was made to maximize compactness; rather, functional and calibration flexibility were deliberately designed into the unit to accommodate anticipated changes and improvements which were indeed made during the development stage.

18.0.2 Sensors

Intake manifold absolute pressure is measured with an accuracy of ± 1 percent, using an aneroid, linear variable differential transformer sensor device. This sensor is mounted on the ECU printed circuit board to implement concurrent calibration of sensor and ECU and to increase reliability by minimizing the number of electrical connections between the sensor and the computing circuits.

Engine speed is sensed using two magnetic reed switches mounted on the ignition distributor casting, adjacent to the drive shaft. Installed on the drive shaft is a magnet assembly. This sensor provides engine phasing as well as engine speed data.

Engine water temperature and intake manifold air temperature are sensed using a high temperature coefficient precision resistor, formed from nickel wire wound on a bobbin, which is epoxy encased. The sensor output is precise and linear over the temperature range encountered.

Data on throttle position and rate of change of throttle motion are provided by a rotating shaft sensor. Mechanical contacts on the shaft slide over a printed circuit board on which electric current carrying tracks are mounted. Rotational information is realized when tracks are crossed as the throttle moves. The discrete voltage levels sensed are processed in the ECU to yield the required data.

18.0.3 Injectors

The fuel valving, metering, and atomizing functions are performed by the injectors, which are located, one for each cylinder, in the vicinity of the intake valves. These injectors are essentially solenoid actuated on/off poppet valves incorporating pintles designed for metering and atomization. Since a constant fuel pressure differential is maintained across the injector, the rate of fuel delivery is proportional to the injector open time, which varies from 2.5 to 10 milliseconds.

18.0.4 Air Flow Calculating Versus Air Flow Sensing EFI Systems

The first generation of Bosch EFI systems were called the D-Jetronic, where D stands for Druck, which means pressure in German. This name is derived from the fact that one of the main inputs to this sytem is intake manifold pressure. In this system the fuel loop consists of the fuel pump, the fuel filter, and the fuel pressure regulator. With constant fuel pressure applied to the injectors, the amount of fuel injected on a per stroke basis is proportional to the timing of the regulator which can be controlled. Air flow can be calculated using displacement, engine speed and manifold density, and the desired air/fuel ratio can be obtained by changing the injector on time.

The next generation of Bosch EFI system was the L-Jetronic system, where L stands for Luftmengenmessung, which means air flow measurement in German. In this system the fuel loop is basically the same as in the D-Jetronic system except that the fuel pressure regulator is connected by a hose to the intake manifold so that the fuel pressure is a function of the manifold pressure and the pressure loop across the injectors is thus kept constant.

Also, in this system, the air flow rate is measured by an air flow meter whose moveable measuring plate is opened by the air stream against the force of a spring. The position of the measuring plate is sensed by a potentiometer. Its voltage is proportional to the volume of air flow and is one of the main input signals into the electronic control unit. The second input is engine speed taken from the distributor.

Measurement of air flow is said by Bosch to exhibit the following advantages.

1. Compensation of tolerances which are due to wear, deposits in the combustion chamber, or changes in the valve adjustments.

2. Compensation of engine speed-dependent volumetric efficiency.

3. No necessity of acceleration enrichment because the air flow signal precedes the filling of the cylinders.

4. Improved idling stability.

5. Insensitivity to changes in the exhaust back pressure caused by thermal or catalytic reactors.

6. Insensitivity of the system to EGR because only the fresh air portion is measured.

18.0.5 Closed Loop/Electronic Fuel Injection Systems

The term closed loop requires some discussion. One use of the term closed loop is to describe adaptive systems where feedback of output directly influences the input. This is so called extremum seeking adaptive control. Another use of the term closed loop is to describe systems where the output is used for error correction to some programmed parameter. Current closed loop fuel management systems are of this latter type.

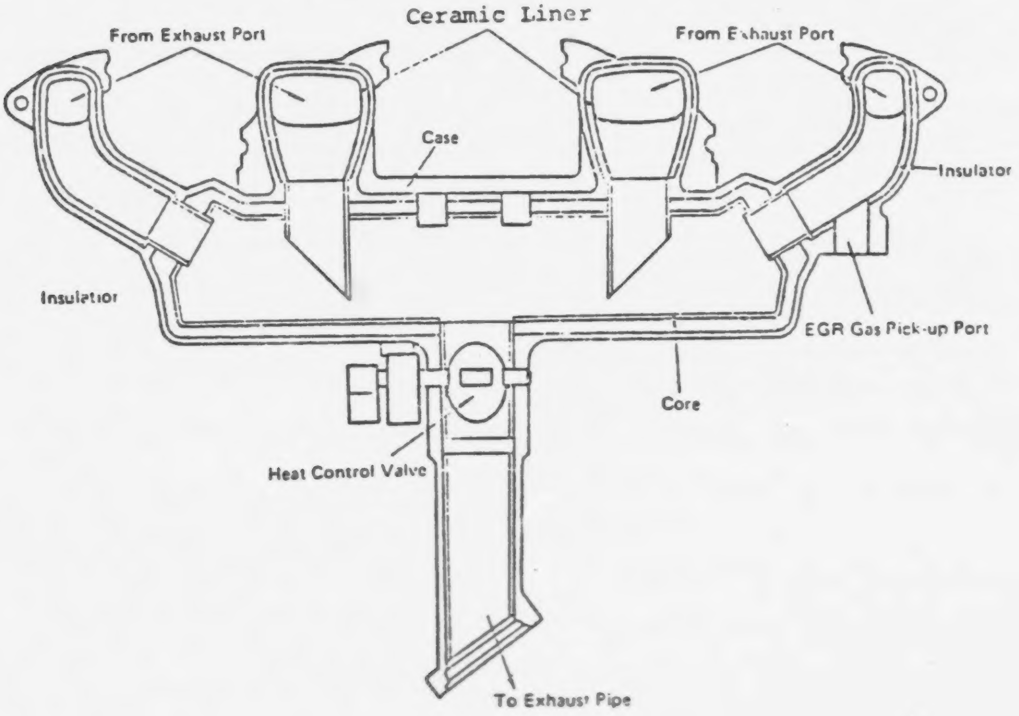
19.0 Thermal Reactor (Insulated With Core and Insulated Without Core)

Thermal reactors have been used to promote the gas-phase oxidation of hydrocarbons and carbon monoxide. Excess oxygen and high temperatures are required to insure efficient oxidation. Early versions have required a fuel-rich exhaust and air injection to insure that high thermal-reactor temperatures could be maintained. Such a system was particularly suited to the rotary engine because of its inherently high hydrocarbon exhaust levels. Unfortunately, the requirement to operate the engine fuel rich necessarily results in decreased fuel economy. Better design of the thermal-reactor system appears to allow use of a lean thermal reactor which would not suffer the fuel economy penalty of the rich thermal reactor. Air injection might still be required to insure that the oxidizing mixture is available at all engine operating conditions.

Many lean-burn engines also include a simple thermal reactor, often no more than a somewhat enlarged, thermally insulated exhaust manifold. Because of the lower exhaust temperatures of the lean-burn engines, thermal reactor performance is limited but usually adequate to give approximately a 50% reduction in hydrocarbons. Since the introduction of the oxidation catalyst, thermal reactors are now found primarily on rotary, lean-burn, and stratified-charge engines.

19.0.1 Thermal Reactor

Thermal Reactor Configuration


Ceramic Liner
From Exhaust Port
From Exhaust Port
Case
Insulator
Insulation
EGR Gas Pick-up Port
Core
Heat Control Valve
To Exhaust Pipe

18.0.6 Bendix Closed Loop EFI Systems

A closed loop modification to the above Bendix EFI system has been made to improve emission performance. The modification consists of a zirconium dioxide transducer used to sense the oxygen level in exhaust gas and to send a signal to the Electronic Control Unit to modify the air fuel ratio by adjusting the time duration of fuel injection pulses. The key element in this modification is O_2 sensor--the zirconium dioxide transducer.

A Bendix closed loop system has been integrated with 3-way catalytic converters in a General Motors Vega and tested by General Motors. The O_2 sensor is installed up stream of the 3-way converter. General Motors is evaluating this applicatio as compared to a 3-way closed loop carburetor systems as described below.

The ECU is not significantly affected by this modification, although additional circuits are required to perform this function.

18.0.7 Closed Loop Carburetor System

Whereas Electronic Fuel Injection proponents claim technical advantages of closed loop EFI systems over closed loop carburetor systems (e.g., time lag of carbureted engine four to six time that of fuel injected engine, lag due to relative density of fuel-air, liquid fuel dropout to manifold, dynamics limitatio affects accuracy, carburetor proponents point out that economc advantages could be realized if carburetors were used in closed loop systems to meet emission requirements since use of conventional hardware would result in minimal production disruption.

General Motors has adapted a four-barrel Venturi carburetor in a closed loop air-fuel ratio control system and installed this system on an intermediate Nova sedan with a 400 CID engine and performed tests on this vehicle.

The three-way catalyst material in this system is located in the same under floor converter used in the oxidizer-only catalyst systems designed to meet 1975 through 1979 Federal emission standards. In this system 0_2 exhaust gas sensors are used; one samples the tail pipe exhaust system at the converter outlet and one samples the engine and exhaust gas at the exhaust manifold. The four-barrel carburetor contains a special set of metering rods and a vacuum regulator to provide the mechanism to vary air-fuel ratio in response to command signals from the electronic controller. The closed throttle switch on the carburetor assembly provides for one of the open loop functions to be described and the cold start switch senses engine coolant temperature for another open loop function.

A solid state electronic controller provides the control logic necessary to process the signals from the various sensors and generate the command signal to modulate the air-fuel ratio.

The closed loop carburetor performs all of the functions of a conventional carburetor in metering fuel over a wide variety of engine speeds, loads, and operating temperatures. The closed loop function is designed into the primary main metering circuit to provide closed loop control of air-fuel ratio at the converter window for part throttle, warmed-up driving conditions. The fuel metering circuits provide conventional pre-calibrated, or open loop, control of fuel for additional driving conditions, which include wide-open throttle, closed throttle, cold start, and rapid throttle openings.

In order to provide the mechanism for varying air-fuel ratio in response to an electrical command signal, a vacuum regulator and a special set of metering rods are used in the primary main circuit of a four-barrel carburetor. The power system, actuated by manifold vacuum, and the adjustable part throttle circuit, are retained.

The vacuum regulator is an electro-mechanical transducer that supplies a control vacuum signal ranging from zero to approximately 8 in Hg as a function of an electrical current, with manifold vacuum used as the source vacuum.

The objective of the closed loop system is to minimize the production of HC, CO, and NOx in the tail pipe exhaust gas by operating the engine at the air-fuel ratio which produces the highest mutual conversion efficiencies in the three-way catalytic converter. The two exhaust gas sensors analyze the gas composition as it leaves the engine and again as it leaves the three-way converter. The electronic control logic utilizes the information from the exhaust gas sensor signals to generate commands to the vacuum regulator to eigher hold the air-fuel ratio constant or make a correction in the rich or lean direction to provide the correct mixture for operation at the three-way converter window. When the electronic controller is responding to the two exhaust gas sensors, the system is said to be in the closed loop mode since the engine-out exhaust is being analyzed. When the control logic is responding to the closed throttle switch or cold start switch, the system is operating in an open loop mode.

19.1 Thermal Reactor Manufacturing Costs

Bill of Material

4-Cylinder Engine

Part	Material	Weight	Material Costs	Labor Costs	Labor Overhead	Manufacturing Costs	Reference
Exhaust Manifold	Cast Iron	14.75	4.4250	.1250	.0500	4.6000	.30/lb. EPA sketch
Liners	Ceramic	2.00	4.0000	.0413	.0165	4.0578	$2/lb.
Core Liners	H.T. Steel	2.00	2.0000	.0413	.0165	2.0578	$1/lb.
Core	H.T. Steel	3.00	2.0000	.1250	.0500	2.1750	$1/lb.
Insulation	Asbestos	1.00	.5000	.0413	.0165	.5578	$50/lb.
Total						13.4484	
Vehicle ASM				.1250	.0500	.1750	
Eng. Mod				.1250	.0500	.1750	
Total						13.7984	

19.2 Thermal Reactor Tooling Costs

Amortization Per Piece

Part	Economic Volume	1 Year Recurring Tooling	3 Year Nonrecurring Tooling	12 Year Machinery and Equipment	12 Year Launching Costs	40 Year Land and Building	Amortization per Per Piece
Exhaust Manifold	400,000	.1250 50,000	.1250 150,000	.5000 2,400,000	.0500 240,000	-	.8000
Liners	1,000,000	.0200 20,000	.0200 60,000	.0200 240,000	.0020 24,000	-	.0620
Core Liners	1,000,000	.0100 10,000	.0100 30,000	.0100 120,000	.0010 12,000	-	.0310
Core	400,000	.0500 20,000	.0500 60,000	.0500 240,000	.0050 24,000	-	.1550
Insulation	1,000,000	.0100 10,000	.0100 30,000	.0100 120,000	.0010 12,000	-	.0310
Total							1.0790
Vehicle ASM	400,000	.0250 10,000	.0250 30,000	.0250 120,000	.0025 12,000	-	.0775
Engine Mod	400,000	.0250 10,000	.0250 30,000	.0250 120,000	.0025 12,000	-	.0775

Research & Development - $400,000 per year for 3 years for 400,000 pieces per year or $1.0000 per vehicle.

19.3 Thermal Reactor Total Manufacturing Costs

Part	Material	Labor	Plant Overhead	Plant Mfg. Costs	Tooling Exp.	Tooling Inv.	Corp. Alloc. .20MC*	Corp. Profit .20MC*	Vendor Mfg. Costs
Exhaust Manifold	4.4250	.1250	.0500	4.6000	.2500	.5500	.9200	.9200	7.2400
Liners	4.0000	.0413	.0165	4.0578	.0400	.0220	.8116	.8116	5.7429
Core Liners	2.0000	.0413	.0165	2.0578	.0200	.0110	.4116	.4116	2.9119
Core	2.0000	.1250	.0500	2.1750	.1000	.0550	.4350	.4350	3.2000
Insulation	.5000	.0413	/0165	.5578	.0200	.0110	.1116	.1116	.8119
Total				13.4484					19.9067

*MC = Manufacturing Costs

19.4 Thermal Reactor Retail Price Equivalent

Part	Plant Vendor Costs	R&D	Tools and Equip.	Corp. Alloc. .20VC*	Corp. Profit .20VC*	Dealer Markup .40VC*	Vehicle Retail Price Equivalent
Thermal Reactor	19.9067	1.000	-	3.9813	3.9813	8/9627	36.8321
Vehicle	.1750		.0775	.0350	.0350	.0700	.3925
Engine Mod	.1750		.0775	.0350	.0350	.0700	.3925
Total							37.6171

The uninsulated thermal reactor costs are $35.37 excluding vehicle assembly and engine modifications.

*VC = Vendor Costs

19.5 Thermal Reactor Cost Comparison To Aftermarket Selling Prices

The Mazda Rotary Engines are selling the thermal reactors for $186.93 to $255.19 for RX-2 amd RX-3 engines. This selling price includes a five year warranty.

Using discount data:

	186.93	Est. Vendor Costs	Retail Price Equivalent
Discount 1/4	46.73		
Discount 1/5	37.40	19.83	37.49

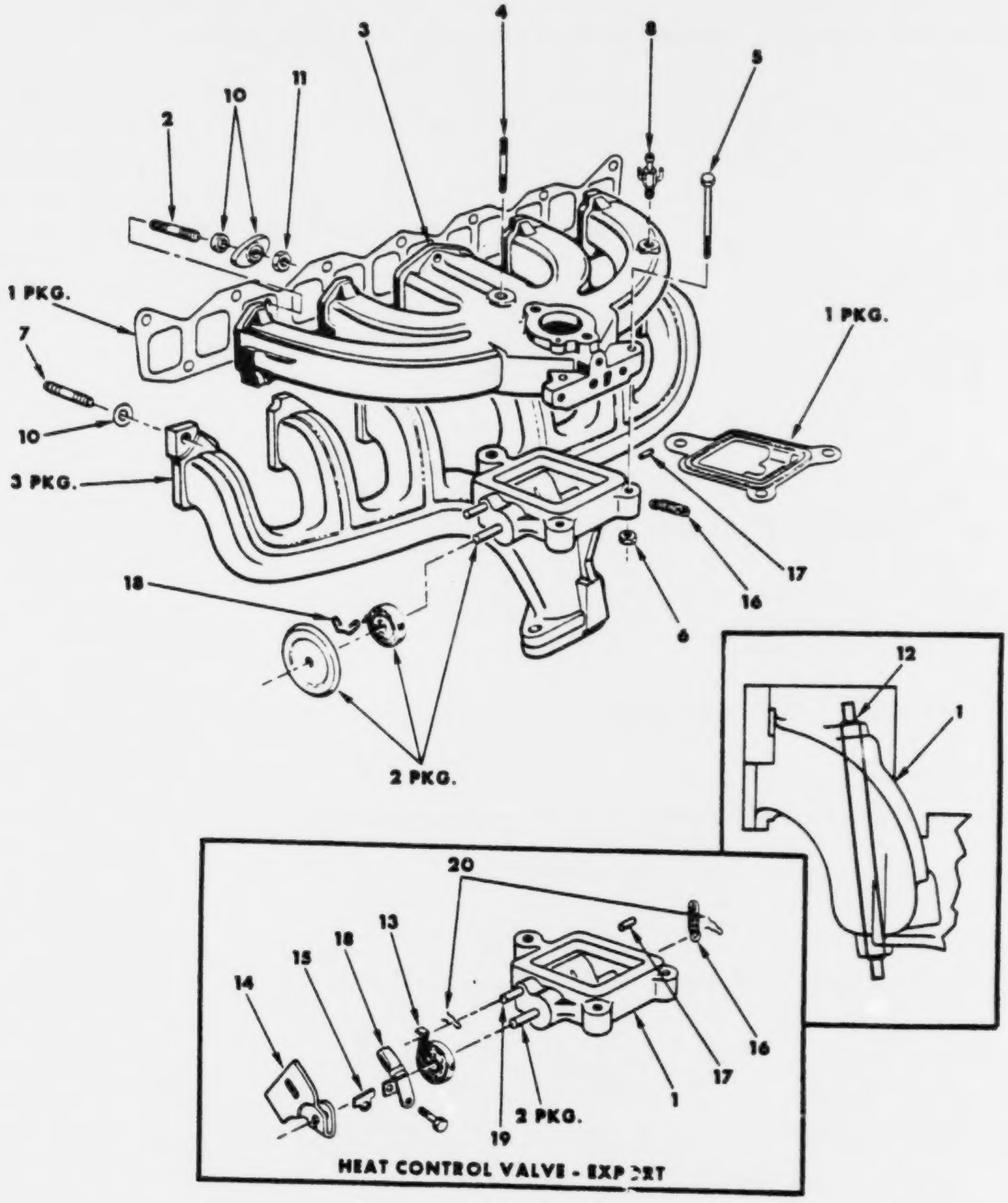
The exhaust manifold on a CVCC Honda sells for $79.20. Using the discount formula, the vendor cost is 79.20 ÷ 4 = $19.80.

19.6 Thermal Reactor Cost Methodology

The weight data are estimates based on 4 cylinder exhaust data. The material costs are estimates based on material selections.

The design data are from the sketch in 19.0.

7156500 INTAKE AND EXHAUST MANIFOLD WITH HEAT CONTROLS (6 CYLINDER ENGINE)


4
3
8
5
2
10
11
1 PKG.
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3 PKG.
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2 PKG.
12
1
20
13
18
15
14
16
17
1
2 PKG.
19
HEAT CONTROL VALVE - EXPORT

20.1 Exhaust Manifold (Stock)

BILL OF MATERIAL
MANUFACTURING COSTS

Part	Material	Weight	Mat Costs	Labor	Overhead	Mfg Costs	Reference
6 Cyl. 225 CID							See B/M
Exh. Manifold	Cast Iron	25.7550	7.7250	.2300	.0920	8.0470	
Gaskets	Composite	.2100	.0840	.0100	.0040	.0980	
Hardware	Steel	.3730	.0746	.0100	.0040	.0886	
Total			7.8836	.2500	.1000	8.2336	
8 Cyl. 318 CID							See B/M
LH Ext. Manifold	Cast Iron	22.8000	6.8400	.2300	.0920	7.1620	
RH Ext. Manifold	Cast Iron	17.2500	5.1750	.2300	.0920	5.4970	
Gaskets	Composite	.1900	.0760	.0100	.0040	.0900	
Hardware	Steel	.8050	.1610	.0100	.0040	.1750	
Total			12.2520	.4800	.1920	12.9240	
6 Cylinder							
Asm Vehicle	Asm.	-	-	.1252	.0500	.1752	
Eng. Mod.	-	-	-	-	-	-	
8 Cylinder							
Asm Vehicle	Asm.	-	-	.1500	.0600	.2100	
Eng. Mod.	-	-	-	-	-	-	

20.1 Bill of Material

C 75 VL41 F24 111.0 B 1975 Valiant Lowline 4-Door Sedan, (225 C.I.D. 6 Cylinder)

U-P-G	Line	Part No.	Description	Quantity	Weight
Cur=17 Rev=29	Cur=23 Rev=35	39	29 (Of a 3R, or a 31, If a New Line)	48	55
30A10	100	3769990	Manifold-Intake (3769979) C/N	1	19.730
30A10	105	3751633	Exhaust Manifold 225	1	25.755
30A10	110	3751635	Gasket-Intake to Exhaust Manifold	1	.040
30A10	115	6030209	Stud-Exhaust Attachments to Intake	10	.300
30A10	120	6030003	Bolt-Exhaust Manifold Attachments to Intake	2	.146
30A10	125	6030210	Nut-Exhaust Manifold and Intake	2	.020
30A10	130	1947762	Gasket-Exhaust and Intake Manifold	1	.170
30A10	135	3751636	Washer-Manifold Attachments	10	.280
30A10"		(Secondary Group) Manifolds		28	46.441

20.1 **Bill of Material**

C 75 VL41 E24 111.0 B 1975 Valiant Lowline 4-Door Sedan, (318 C.I.D. V-8 2-BBL)

U-P-G	Line	Part No.	Description	Quantity	Weight
Cur=17 Rev=29	Cur=23 Rev=35	39	29 (Of a 3R, or a 31, If a New Line)	48	55
30A10	100	3830940	Intake Manifold 318 CID	1	43.000
30A10	105	2536514	Gasket	2	.190
30A10	110	0181095	Bolts and Washers	2	.100
30A10	115	3671597	Gasket-Intake Manifold FT	1	.010
30A10	116	3671598	Gasket-Intake Manifold RR	1	.010
30A10	120	6027332	Bolts and Washers-Intake Manifold	12	.720
30A10	125	3698458	Shield-Intake Manifold Heat	1	.480
30A10	130	3830904	Exhaust Manifold Left 318 CID	1	22.800
30A10	135	3830685	Exhaust Manifold Right 318 CID	1	17.250
30A10	140	6025991	Stud-Carburetor Attachments	5	.150
30A10	145	9421360	Bolt-Exhaust Manifold Attachments	3	.120
30A10	150	2121223	Washer Exhaust Manifold Attachments	5	.225
30A10	160	0115729	Nut	4	.040
30A10	165	2121223	Washer Exhaust Manifold Attachments	8	.360
30A10	170	6028356	SC-Exhaust Manifold	1	.060
30A10	180	0181089	Bolt	2	.060
30A10	1025	6025991	Stud-Carburetor Attachments	4	.120
30A10		(Secondary Group) Manifolds		54	85.695

20.2 **Exhaust Manifold (Stock)**

TOOLING AMORTIZATION

Part	Economic Volume Per Year	1 Year Recurring Tooling	3 Year Non-Recurring Tooling	12 Year Machinery Equipment	12 Year Launching Costs	40 Year Land & Buildings	Amortization Per Piece
6 Cyl. 225 CID							
Exhaust Manifold	240,000	.3333 80,000	.3333 240,000	.8333 2,400,000	.1944 560,000	-	1.6944
Gaskets	5,000,000	.0040 20,000	.0017 25,000	.0025 150,000	.0002 15,000	-	.0084
Hardware	10,000,000	.0010 10,000	.0010 30,000	.0005 60,000	.0000 6,000	-	.0025
Vehicle Assembly	240,000	.1000 24,000	.1000 72,000	.0417 120,000	.0042 12,000	-	.2459
Total		.4383	.4360	.8780	.1988		1.9512
8 Cyl. 318 CID							
Exhaust Manifold	400,000	.2500 100,000	.2500 300,000	.6667 3,200,000	.2667 1,280,000	-	1.4333
Gaskets	5,000,000	.0040 20,000	.0017 25,000	.0025 150,000	.0002 15,000	-	.0084
Hardware	10,000,000	.0010 10,000	.0010 30,000	.0005 60,000	.0000 6,000	-	.0025
Vehicle Assembly	400,000	.1000 40,000	.1000 120,000	.0250 120,000	.0025 12,000	-	.2275
Total		.3550	.3527	.6947	.2694		1.6718

20.3 Exhaust Manifold Stock

TOTAL MANUFACTURING COSTS

Part	Mat	Labor	Plant Over-Head	Plant Mfg Costs (MC)	Tooling Exp.	Tooling Inv.	.20/MC Corp Costs	.20/MC Corp Profit	Mfg/ Vendor Costs
6 Cylinder 225 CID									
Exhaust Manifold	7.7250	.2300	.0920	8.0470	.6667	1.0277	1.6094	1.6094	12.960
Gaskets	.0840	.0100	.0040	.0980	.0057	.0027	.0196	.0196	.145
Hardware	.0746	.0100	.0040	.0886	.0020	.0006	.0177	.0177	.126
Total	7.8836	.2500	.1000	8.2336	.6743	1.0310	1.6467	1.6467	13.232
8 Cylinder 318 CID									
LH Exhaust Manifold	6.8400	.2300	.0920	7.1620	.2500	.4667	1.4324	1.4324	10.743
RH Exhaust Manifold	5.1750	.2300	.0920	5.4970	.2500	.4667	1.0994	1.0994	8.412
Gaskets	.0760	.0100	.0040	.0900	.0057	.0027	.0180	.0180	.134
Hardware	.1610	.0100	.0040	.1750	.0020	.0006	.0350	.0350	.247
Total	12.2570	.4800	.1920	12.924	.5077	.9366	2.5848	2.5848	19.533

20.4 Exhaust Manifold Stock

RETAIL PRICE EQUIVALENT
AT THE VEHICLE LEVEL

Part	Plant Vendor Costs (VC)	R&D	Tools and Equip	Corp Allocation .20 VC	Corp Profit .20 VC	Dealer Markup .40 VC	Vehicle Retail Price Equivalent
6 Cyl. 225 CID							
Exh. Manifold	13.2324	-	-	2.6465	2.6465	5.2930	23.8183
Vehicle Assem.	.1752	-	.2459	.0350	.0350	.0701	.5613
Total							24.3796
8 Cyl. 318 CID							
Exh. Manifold	19.5380	-	-	3.9076	3.9076	7.8152	35.1684
Vehicle Assem.	.2100	-	.2275	.0420	.0420	.0840	.6055
Total							35.7739

20.5 Exhaust Manifold (Stock)

Cost Comparison to Aftermarket Selling Prices

Using Chilton 1975 selling price data for 6 cylinder and 8 cylinder manifolds, we made the following comparison.

	Selling Price Aftermarket	Discount 1/4	Discount 1/5
Chilton 225 CID 6 Cylinder	$51.98	$12.99	$10.39
Estimate 225 CID 6 Cylinder	-	13.23	
Chilton 318 CID 8 Cylinder RH	$41.76	$10.44	$ 8.35
Chilton 318 CID 8 Cylinder LH	36.33	9.08	7.26
Estimate 318 CID 8 Cylinder RH		$10.74	
Estimate 318 CID 8 Cylinder LH		8.41	

20.6 Exhaust Manifold (Stock)

Cost Methodology

Chrysler weight data and Bill-of-Material costs were used. Labor and material costs are estimated, based on today's technologies and economies of scale.

20.7 Exhaust System Manifolds (Stock)

Applications

The 6-cylinder data can be proportioned to other in-line engines by CID.

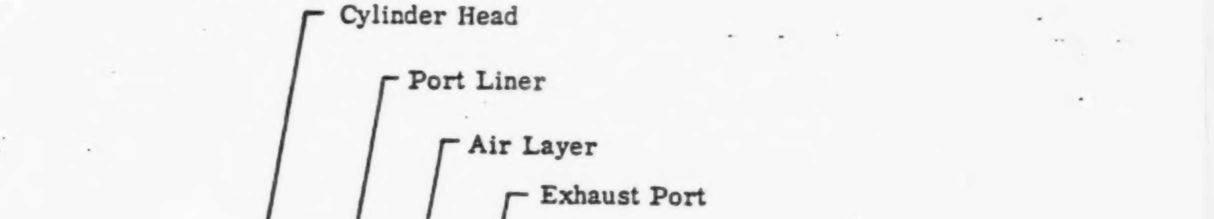
The 8-cylinder data can also be proportioned to other V-8 engines by CID.

21.0 Exhaust Port Liners

The exhaust port liners are inserted in the exhaust cored outlet which provides a smooth flow heating chamber insulated from the head casting by an air gap. The thin section of the liner provides a quick heat surface and chamber for burning the exhaust gases.

The liner is a fabricated and welded shape that is inserted in the head casting. The costs will include the liners and the delta costs required in the head casting to provide for the assembly.

Exhaust Port Liner


Cylinder Head
Port Liner
Air Layer
Exhaust Port
Exhaust Valve
Air Suction H
to Exhaust
Manifold

21.1 Exhaust Port Liners

MANUFACTURING COSTS - 4-CYLINDER ENGINE

Part	Material	Weight	Material Costs	Material Costs	Labor Over-Head	Mfg Costs
Liners	HT Steel	2.100	2.100	.3750	.1500	2.6250
Head casting	--	--	--	.2500	.1000	.3500
Liner Assembly	--	--	--	.3500	.1400	.4900
Total						3.4650

21.2 Exhaust Port Liners

TOOLING COSTS

AMORTIZATION PER PIECE

4-Cylinder Engine

Part	Economic Volume Per Year	1-Year Recurring Tooling	3-Year Non Recurring Tooling	12-Year Machinery Equipment	12-Year Launching Costs	40-Year Land & Buildings	Amortization Per Piece
		.0750	.0750	.0250	.0025		
Port Liners	400,000	30,000	90,000	120,000	12,000	--	.1775
		.1000	.1000	.1000	.0100		
Head Casting	400,000	40,000	120,000	480,000	48,000	--	.3100
		.0250	.0250	.0100	.0010		
Liner Assembly	400,000	10,000	30,000	48,000	48,000	--	.0610
Total							.5485

21.3 Exhaust Port Liners

TOTAL MANUFACTURING COSTS

Part	Mat	Labor	Plant Over-Head	Plant Mfg Costs (MC)	Tooling		.20/MC Corp. Costs	/MC Corp. Profit	Mfg/ Ven Cost
					Exp.	Inv.			
Port Liners	2.100	.3750	.1500	2.6250	.1500	.0275	.5250	.5250	3.8
Head Casting	--	.2500	.1000	.3500	.2000	.1100	.0700	.0700	.80
Liner Assembly	--	.3500	.1400	.4900	.0500	.0110	.0980	.0980	.74
Total			3.4650						5.3

21.4 Exhaust Port Liners

RETAIL PRICE EQUIVALENT AT THE VEHICLE LEVEL

Part	Vendor Costs (VC)	R&D	Tools and Equip	Corp Allocation .20 VC	Corp Profit .20 VC	Dealer Markup .40 VC	RPE Vehicle Level
Port LIners	5.3995	--	--	1.0799	1.0799	2.1598	9.7191

21.5 Exhaust Port Liners

COST COMPARISON TO AFTERMARKET SELLING PRICES

This item is not a separate aftermarket product. It is an integral part of the engine head assembly. Using the discount formula (4 x V.C.) we can estimate the delta increase of a head without port liners versus a head with port liners.

Delta increase
4(V.C.) = 5.3995 (4) = $21.5980

21.6 Exhaust Port Liners

The data was estimated using the sketch supplied by EPA. The delta changes to the head casting were included in the estimate. Casting the liners in place was not included in this estimate. The process does not seem practical for cast iron heads. It might be feasible for aluminum heads. In any case, the costs will be similar.

21.7 Exhaust Port Liner Applicators

This estimate was made for a 4-cylinder engine. The costs will be proportional applied to larger CID 4-cylinder engines, 6-cylinder, and 8-cylinder engines.

22.0 Radiator (Stock, with 20% Reduction)

The stock radiator selected for cost analysis is used on the 1975 Satellite 4-door sedan (318 CID V-8). The weight data is detailed in the Chrysler bill of material.

No detailed construction of a radiator was available, so the sketch was developed to illustrate the typical construction.

22.1 Radiator (Stock, with 20% Reduction)

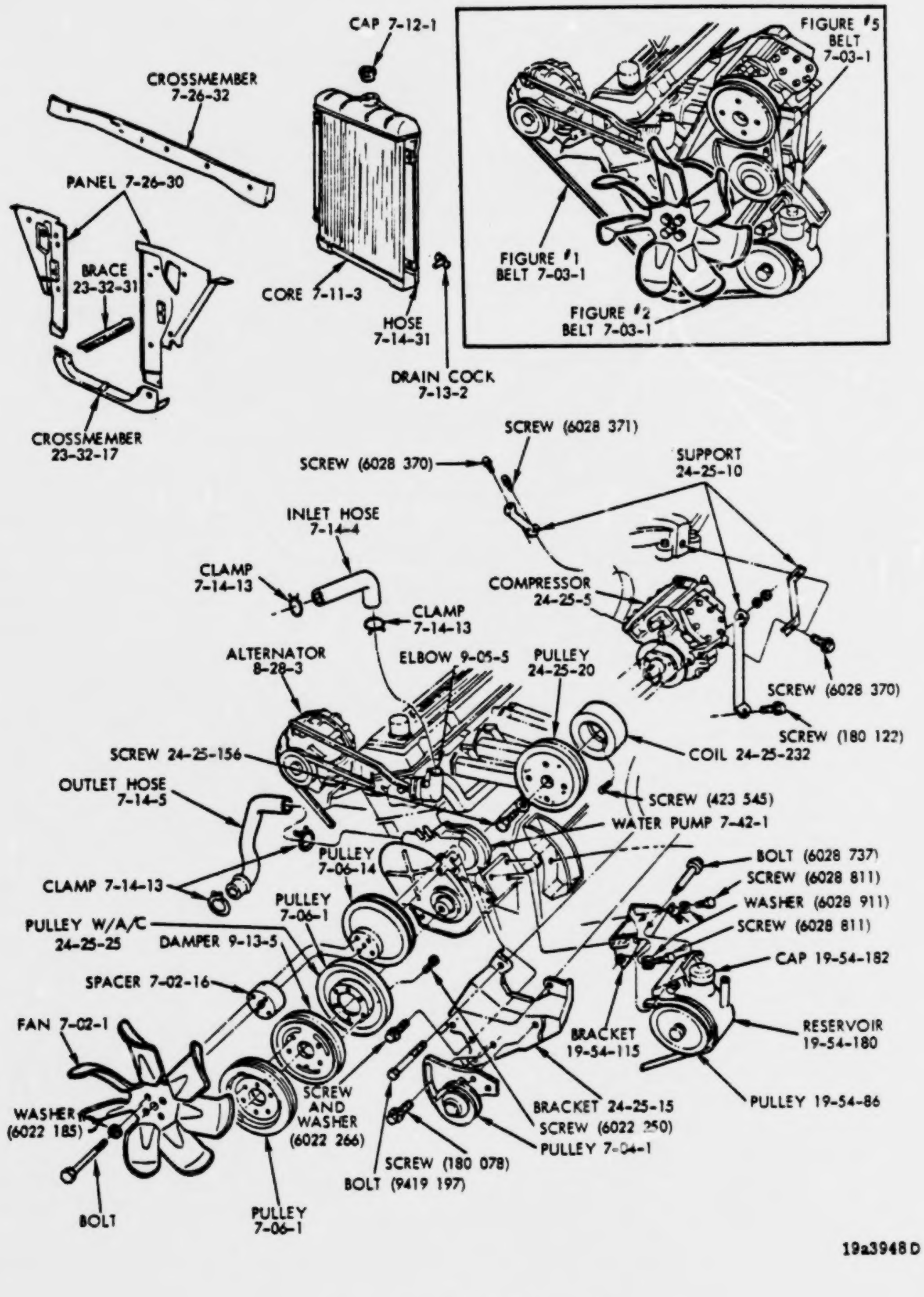
RADIATOR--2 CELL (STOCK)
MANUFACTURING COST

Part	Type Material	Weight	$ Material	$ Labor	OH $ 0.4	$ Mfg Cost	
Radiator Assembly	Brass & Terne	14.78	$6.80	$5.35	$2.14	$14.29	
Cap - Radiator	Steel	.16	.03	.07	.03	.13	Med
Draincock - Rad.	Steel	.04	.01	.06	.02	.09	Med
Inlet Hose	Rubber	.80	.16	.53	.21	.90	F'mla
Outlet Hose	Rubber	.97	.19	.64	.26	1.09	F'mla
Fan Shroud	Plastic	1.90	.76	.12	.05	.93	Hvy
Coolant Tank	Plastic	.95	.38	.10	.04	.52	Hvy
Clamps (4)	Steel	.24	.04	.08	.03	.15	Med
Hardware	Steel	.18	.03	.07	.03	.13	Simple
Total		20.02	$8.40	$7.02	$2.81	$18.23	

22.1 Bill of Material

C 75 RH41 E44 117.5 A 1975 Satellite Highline 4-Door Sedan, (318 C.I.D. V-8 2-BBL)

U-P-G Cur=17 Rev=29	Line Cur=23 Rev=35	Part No. 39	Description 29 (Of a 3R, or a 31, If a New Line)	Quantity 48	Weight 55
30B04	400	3781734	Radiator Assembly	1	14.783
30B04	402	3691920	Shroud-Radiator Fan 19" (Plastic)	1	1.900
30B04	405	6025323	SC & WA-Radiator Core Assembly Attachments	4	.120
30B04	407	6029887	Screw	4	.064
30B04	410	3781830	Cap-Radiator	1	.160
30B04	415	1686198	Drain Cock-Radiator	1	.040
30B04	420	3462166	Hose-Radiator Inlet	1	.800
30B04	425	3870103	Hose	1	.966
30B04	430	0443832	Clamp	2	.120
30B04	435	6025706	Clamp-Lower Hose	2	.120
30B04	436	3781800	Tank Assembly-Coolant Recovery (Plastic P.E.)	1	.950
30B04"		(Secondary Group) Radiator and Hoses		19	20.023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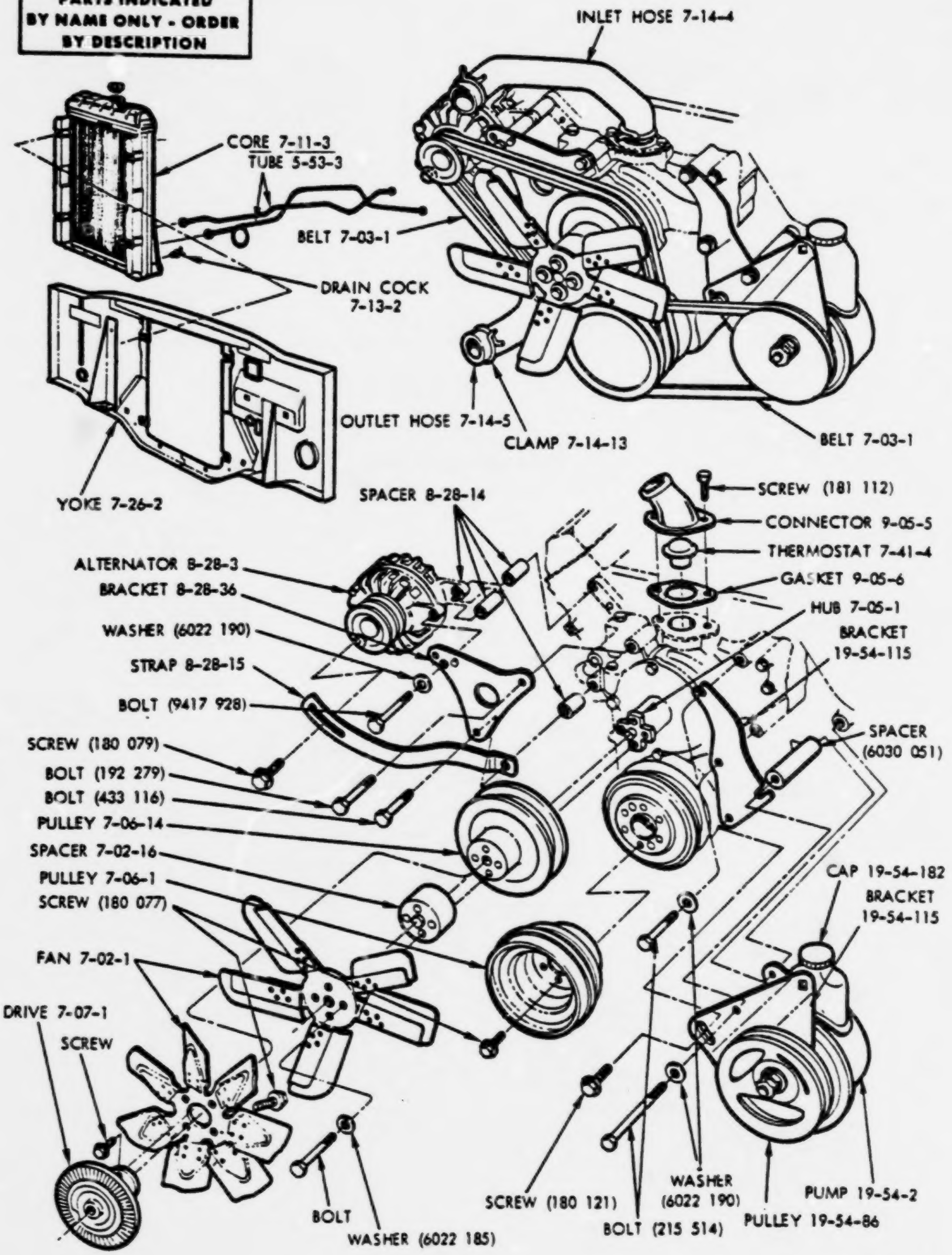
CROSSMEMBER 7-26-32
PANEL 7-26-30
BRACE 23-32-31
CORE 7-11-3
HOSE 7-14-31
DRAIN COCK 7-13-2
CROSSMEMBER 23-32-17
FIGURE #5 BELT 7-03-1
FIGURE #1 BELT 7-03-1
FIGURE #2 BELT 7-03-1
SCREW (6028 371)
SCREW (6028 370)
SUPPORT 24-25-10
INLET HOSE 7-14-4
CLAMP 7-14-13
CLAMP 7-14-13
COMPRESSOR 24-25-5
ALTERNATOR 8-28-3
ELBOW 9-05-5
PULLEY 24-25-20
SCREW (6028 370)
SCREW (180 122)
SCREW 24-25-156
COIL 24-25-232
OUTLET HOSE 7-14-5
SCREW (423 545)
WATER PUMP 7-42-1
PULLEY 7-06-14
BOLT (6028 737)
SCREW (6028 811)
WASHER (6028 911)
SCREW (6028 811)
CLAMP 7-14-13
PULLEY 7-06-1
PULLEY W/A/C 24-25-25
DAMPER 9-13-5
CAP 19-54-182
SPACER 7-02-16
FAN 7-02-1
BRACKET 19-54-115
RESERVOIR 19-54-180
SCREW AND WASHER (6022 266)
WASHER (6022 185)
BRACKET 24-25-15
SCREW (6022 250)
PULLEY 7-04-1
PULLEY 19-54-86
SCREW (180 078)
BOLT (9419 197)
BOLT
PULLEY 7-06-1

19a3948D

COOLING SYSTEM - 6 CYLINDER

PARTS INDICATED BY NAME ONLY - ORDER BY DESCRIPTION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CORE 7-11-3
TUBE 5-53-3
BELT 7-03-1
DRAIN COCK 7-13-2
OUTLET HOSE 7-14-5
CLAMP 7-14-13
BELT 7-03-1
YOKE 7-26-2
SPACER 8-28-14
SCREW (181 112)
CONNECTOR 9-05-5
THERMOSTAT 7-41-4
GASKET 9-05-6
HUB 7-05-1
BRACKET 19-54-115
ALTERNATOR 8-28-3
BRACKET 8-28-36
WASHER (6022 190)
STRAP 8-28-15
BOLT (9417 928)
SCREW (180 079)
BOLT (192 279)
BOLT (433 116)
SPACER (6030 051)
PULLEY 7-06-14
SPACER 7-02-16
PULLEY 7-06-1
SCREW (180 077)
CAP 19-54-182
BRACKET 19-54-115
FAN 7-02-1
DRIVE 7-07-1
SCREW
BOLT
WASHER (6022 185)
SCREW (180 121)
WASHER (6022 190)
BOLT (215 514)
PULLEY 19-54-86
PUMP 19-54-2
19a4404 B

COOLING SYSTEM - 8 CYLINDER

22.2 Radiator (Stock, with 20% Reduction)

Tooling Costs--Amortization Per Part

Part	Economic Volume Per Year	1 Year Recurring Tooling	3 Year Non-Recurring Tooling	12 Year Machinery Equipment	12 Year Launching Costs	40 Year Land & Buildings	Amortization Per Piece
Radiator Assembly	1,000,000	.1000 100,000	.1000 300,000	.3000 3,600,000	.0300 360,000	-	.5300
Radiator Cap	5,000,000	.0050 25,000	.0050 75,000	.0020 120,000	.0002 12,000	-	.0122
Hoses	5,000,000	.0040 20,000	0017. 25,000	.0025 150,000	.0002 15,000	-	.0084
Shroud	1,000,000	.0500 50,000	.0500 150,000	.0200 240,000	.0020 24,000	-	.1220
Coolant Tank	1,000,000	.0250 25,000	.0250 75,000	.0100 120,000	.0010 12,000	-	.0610
Hardware & Clamps	10,000,000	.0010 10,000	.0010 30,000	.0005 60,000	.0000 6,000	-	.0026
Total							.7362

Research and Development Estimates: $150,000 per year for 1,000,000 units per year, or .1500 each

22.3 Radiator (Stock, with 20% Reduction)

TOTAL MANUFACTURING COSTS

Part	Mat	Labor	Plant Over-Head	Plant Mfg Costs (MC)	Tooling		.20/MC Corp Costs	.20/MC Corp Profit	Mfg/ Vend Costs
					Exp.	Inv.			
Radiator Assembly	6.8000	5.3500	2.1400	14.2900	.2000	.3300	2.8580	2.8580	20.5
Radiator Cap	.0300	.0700	.0300	.1300	.0100	.0022	.0260	.0260	.1
Hoses	.3500	1.1700	.4700	1.9900	.0057	.0027	.3980	.3980	2.7
Shroud	.7600	.1200	.0500	.9300	.1000	.0220	.1860	.1860	1.4
Coolant Tank	.3800	.1000	.0400	.5200	.0500	.0110	.1040	.1040	.7
Hardware & Clamps	.0800	.2100	.0800	.3700	.0020	.0006	.0740	.0740	.5
Total	8.4000	7.0200	2.8100	18.2300	.3677	.3685	3.6460	3.6460	26.2
20% Less Radiator	6.7200	6.3180	2.5272	15.5652	.3677	.3685	3.1130	3.1130	

Material is 20% Less

Labor is 10% Less--by Estimate

22.4 Radiator (Stock, with 20% Reduction)

RETAIL PRICE EQUIVALENT
AT THE VEHICLE LEVEL

Part	Plant Vendor Costs (VC)	R&D	Tools and Equip	Corp Allocation .20 VC	Corp Profit .20 VC	Dealer Markup .40 VC	Vehicle Retail Price Equivalent
Stock Radiator	26.2582	.1500	-	5.2516	5.2516	10.5033	47.4148
20% Reduction Radiator	22.5275	.1500	-	4.5055	4.5055	9.0110	40.6995

22.5 Radiator (Stock with 20% Reduction Cost Comparison to Aftermarket Selling Prices

Using the typical discount data of 1/4 to 1/5 and Chilton selling prices, we compare the following:

	Chilton Aftermarket Selling Price	Estimate Vendor Costs	Computed AFT 4x	Computed SP 5x
Radiator Assembly	$112.00	20.53	82.12	102.65

The (20% less) radiator would be about 15% less in total costs or selling prices.

22.6 Radiator (Stock, with 20% Reduction) Cost Methodology

The weight data was obtained from Chrysler data. The detail costs were developed from sketch data of a typical radiator (commercial data). See cost methodology section for the stamped parts cost curves.

22.7 Radiator (Stock with 20% Reduction) Applications to Engines

It can be concluded that the radiators are proportional to the engine sizes and the degree of power options such as air conditioning, power steering, power brakes, and power options.

23.0 Quick Heat Manifolds

Quick heat manifolds provide early heating of the incoming air-fuel mixture. One of these systems is the

Manifold Heat Control Valve

A manifold heat control valve is located in the exhaust manifold of six-cylinder engines and in the right side exhaust manifold on all eight-cylinder engines. The valve directs heated exhaust gases to the heat chamber in the intake manifold beneath the carburetor to help vaporize the fuel mixture during engine warm-up period. On all eight-cylinder engines, when the valve is closed the exhaust gases are directed to the heat chamber through the right side of the exhaust crossover passage; after circulating through the heat chamber, the gases are returned to the exhaust manifold through the left side of the passage.

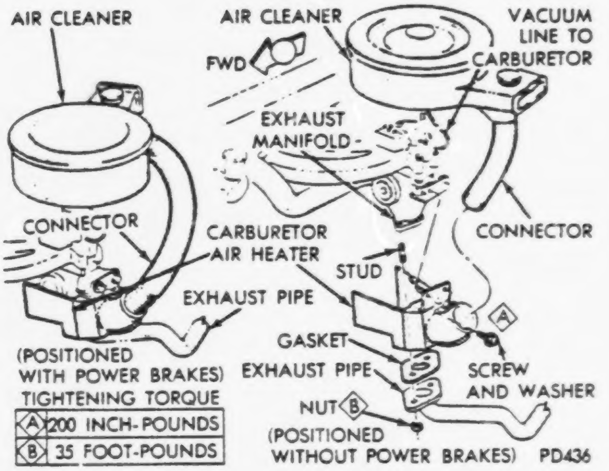
Power Heat Control Valve and Mini-Converter

HC and CO emissions are significantly reduced on some V-8 vehicles for California during engine warm-up by using a mini-converter and a power heat control valve. A vacuum actuator keeps the heat control valve closed during engine warm-up. The exhaust entering the right manifold where the heat valve is located is thereby routed to the left manifold through the crossover passage in the intake manifold. The mini-converter is located adjacent to the left exhaust manifold. Its small size and proximity to the engine cause it to warm up fast and become effective sooner than under-floor catalysts. Having the power heat control valve assures that all of the exhaust is subject to catalytic action during warm-up. Once the engine has begun to warm-up and the under-floor catalyst is hot enough to be effective, the vacuum to the heat control valve is cut off, and the valve opens completely, allowing normal exhaust flow through the right exhaust pipe. The vacuum cut off is accomplished by a temperature sensitive switch in the engine coolant.

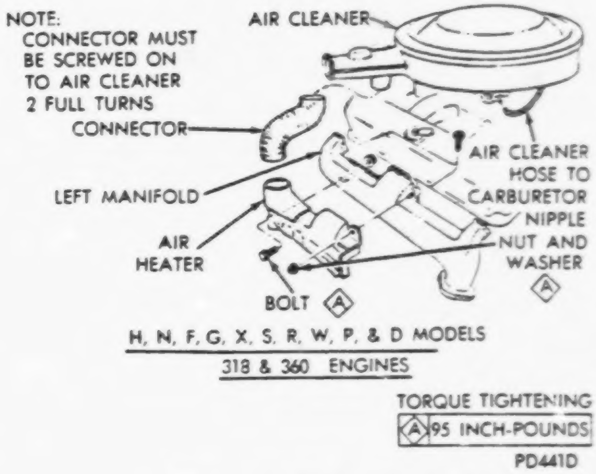
Six-cylinder engines also use the mini-converter, but because all of the exhaust normally goes through one pipe, a conventional thermostatic heat control valve is satisfactory.

23.0 Quick Heat Manifolds

EXHAUST SYSTEM AND INTAKE MANIFOLD

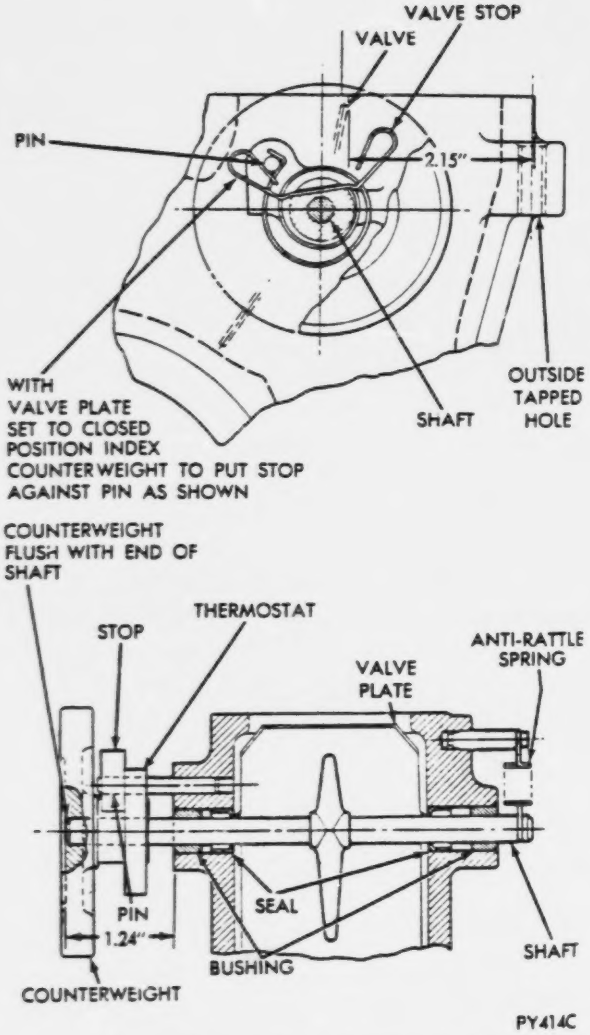

AIR CLEANER
AIR CLEANER
FWD
VACUUM LINE TO CARBURETOR
EXHAUST MANIFOLD
CONNECTOR
CARBURETOR AIR HEATER
CONNECTOR
STUD
EXHAUST PIPE
A
GASKET
EXHAUST PIPE
SCREW AND WASHER
(POSITIONED WITH POWER BRAKES)
TIGHTENING TORQUE
A 200 INCH-POUNDS
B 35 FOOT-POUNDS
NUT B
(POSITIONED WITHOUT POWER BRAKES)
PD436

Carburetor Air Heater—Six Cylinder Engine

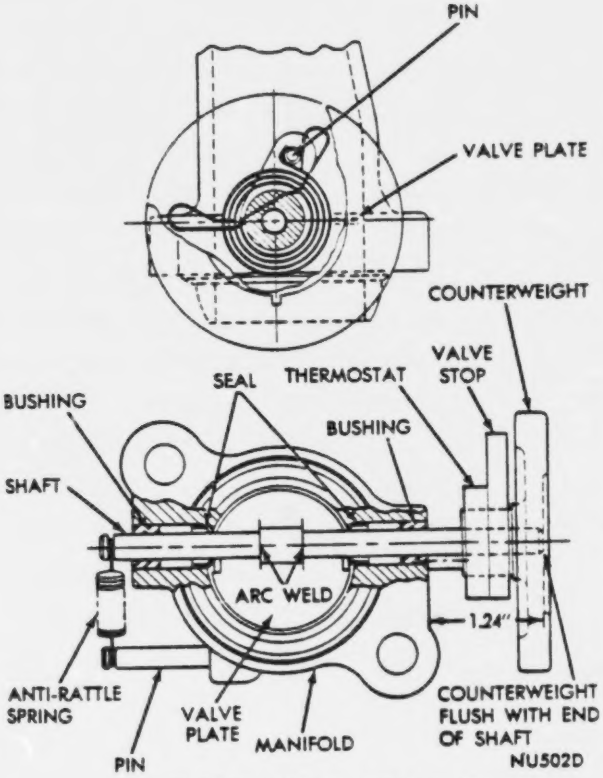

NOTE:
CONNECTOR MUST BE SCREWED ON TO AIR CLEANER 2 FULL TURNS
AIR CLEANER
CONNECTOR
AIR CLEANER HOSE TO CARBURETOR NIPPLE
LEFT MANIFOLD
AIR HEATER
NUT AND WASHER A
BOLT A
H, N, F, G, X, S, R, W, P, & D MODELS
318 & 360 ENGINES
TORQUE TIGHTENING
A 95 INCH-POUNDS
PD441D

Carburetor Air Heater—(318-360)

23.0 Quick Heat Manifolds


VALVE STOP
VALVE
PIN
2.15"
WITH VALVE PLATE SET TO CLOSED POSITION INDEX COUNTERWEIGHT TO PUT STOP AGAINST PIN AS SHOWN
SHAFT
OUTSIDE TAPPED HOLE
COUNTERWEIGHT FLUSH WITH END OF SHAFT
STOP
THERMOSTAT
VALVE PLATE
ANTI-RATTLE SPRING
PIN
SEAL
1.24"
BUSHING
SHAFT
COUNTERWEIGHT
PY414C

Manifold Heat Control Valve—Six Cylinder


PIN
VALVE PLATE
COUNTERWEIGHT
BUSHING
SEAL
THERMOSTAT
VALVE STOP
BUSHING
SHAFT
ARC WELD
1.24"
ANTI-RATTLE SPRING
VALVE PLATE
MANIFOLD
PIN
COUNTERWEIGHT FLUSH WITH END OF SHAFT
NU502D

Manifold Heat Control Valve—(318-360)

23.1 Quick Heat Manifold

BILL OF MATERIAL

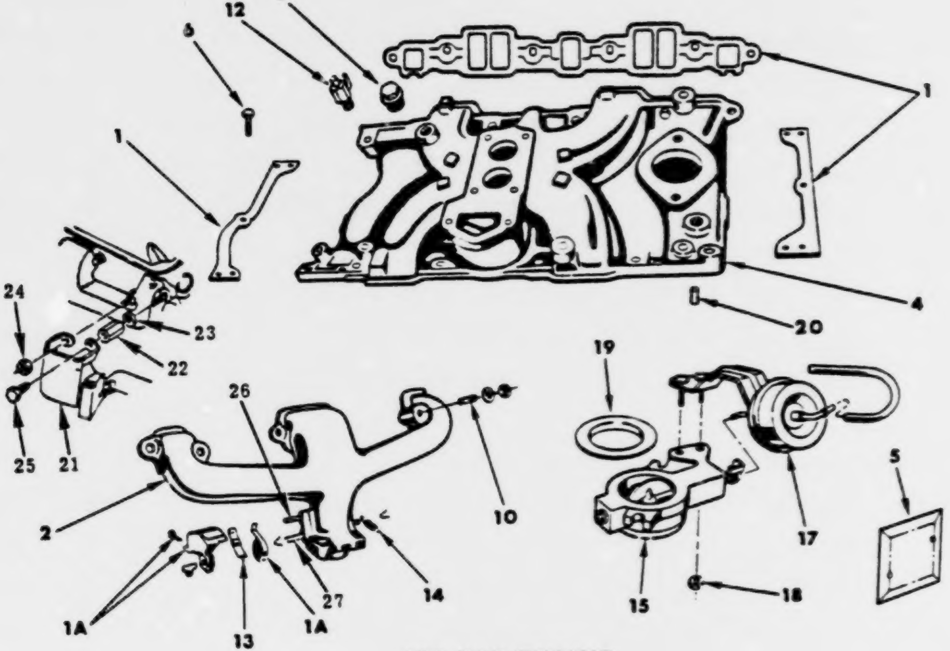
318 CID - 8 CYLINDER

30A10	100	3830940	INTAKE MANIFOLD 318 CID	1	43.000
30A10	105	2536514	GASKET	2	.190
30A10	110	0181095	BOLTS & WA	2	.100
30A10	115	3671597	GASKET-INTAKE MANIFOLD FT	1	.010
30A10	116	3671598	GASKET-INTAKE MANIFOLD RR	1	.010
30A10	120	6027332	BOLT & WA-INTAKE MANIFOLD	12	.720
30A10	125	3698458	SHIELD-INTAKE MANIFOLD HEAT	1	.480
30A10	130	3830904	EXHAUST MANIFOLD LEFT 318 CID	1	22.800
30A10	135	3830685	EXHAUST MANIFOLD RIGHT 318 CID	1	17.250
30A10	140	6025991	STUD-CARG ATTG	5	.150
30A10	145	9421360	BOLT-EXH MANIF ATTG	3	.120
30A10	150	2121223	WASHER EXH MANIF ATTG	5	.225
30A10	160	0115729	NUT	4	.040
30A10	165	2121223	WASHER EXH MANIF ATTG	8	.360
30A10	170	6028356	SC-EXHAUST MANIFOLD	1	.060
30A10	180	0181089	BOLT	2	.060
30A10	1025	6025991	STUD-CARB ATTG	4	.120
30A10			(SECONDARY GROUP) MANIFOLDS	54	85.695
30B02	200	4027056	BODY-AIR CLEANER	1	2.750
30B02	220	2951789	COVER-AIR CLEANER HSG W/SEAL	1	1.350
30B02	225	2206376	ELEMENT ASSY-AIR CLEANER	1	.650
30B02	230	6030729	WING NUT AIR CLEANER	1	.013
30B02	235	1947797	GASKET-AIR CLEANER TO CARB	1	.010
30B02	240	2951394	BALE-AIR CLEANER ATTG	1	.080
30B02	244	6024015	SCR & WA-BRKT TO BRAKE PEDAL BRKT	2	.060
30B02	245	3462452	CONNECTOR-STOVE TO AIR CLR	1	.180
30B02	247	3698475	AIR HEATER-CARBURETOR	1	.600
30B02	249	2951790	GASKET-AIR CLEANER	1	.040
30B02			(SECONDARD GROUP) AIR CLEANER	11	5.733

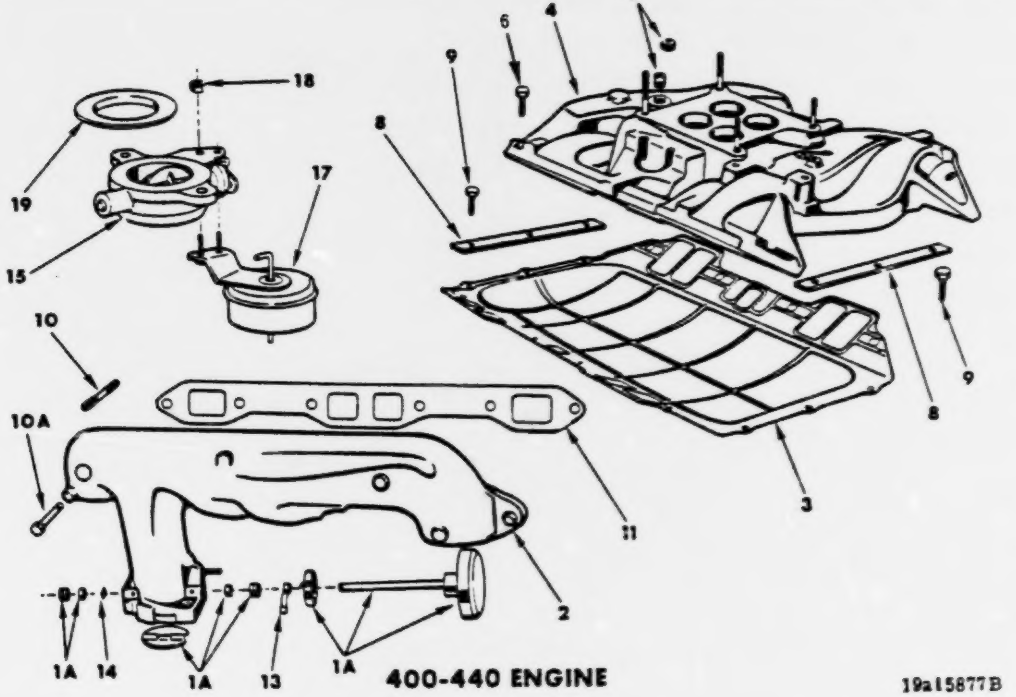
BILL OF MATERIAL

225 CID - 6 CYLINDER

30A10	100	3769990	MANIFOLD-INTAKE (3769979) C/N	1	19.730
30A10	105	3751633	EXH MANIFOLD 225	1	25.755
30A10	110	3751635	GASKET-INTAKE TO EXH MAN	1	.040
30A10	115	6030209	STUD-EXH MANIF ATTG TO INTAKE	10	.300
30A10	120	6030003	BOLT-EXH MANIF ATTG TO INTAKE	2	.146
30A10	125	6030210	NUT-EXH MANIF & INTAKE	2	.020
30A10	130	1947762	GASKET-EXHAUST AND INTAKE MAN	1	.170
30A10	135	3751636	WASHER-MANIFOLD ATTG	10	.280
30A10		(SECONDARY GROUP) MANIFOLDS		28	46.441
30B02	200	3769024	HOUSING AIR CLEANER	1	3.300
30B02	221	3577759	COVER-AIR CLEANER HSG W/SEAL	1	1.490
30B02	223	2536626	GASKET-AIR CLEANER TO CARB	1	.020
30B02	224	2951393	BALE-AIR CLEANER ATTG	1	.060
30B02	225	1739547	ELEMENT ASSY-AIR CLEANER	1	.840
30B02	226	3769049	CONNECTOR-AIR HEATER	1	.162
30B02	230	6030729	WING NUT AIR CLEANER	1	.013
30B02	231	3830699	HTR-CARB AIR	1	.700
30B02	232	0181064	BOLT-HEATER ATTG	2	.030
30B02	233	6025004	NUT-DUCT MOUNTING	1	.010
30B02	234	6023092	SC & WA-DRAIN COVER ATTG	1	.010
30B02	270	9428266	SCREW	2	.010
30B02	275	3830700	SHIELD-SPARK PLUG HEAT	1	.413
30B02		(SECONDARY GROUP) AIR CLEANER		15	7.058


7
12
6
1
1
24
23
22
4
20
19
26
10
25
21
2
17
5
1A
13
27
1A
14
15
18

318-360 ENGINE


7
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18
8
17
19
15
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10A
9
8
3
11
2
1A
14
1A
13
1A

400-440 ENGINE

19a15877B

MANIFOLD WITH HEAT CONTROL
8 CYLINDER

23.1 Quick Heat Manifold

Manufacturing Costs

Bill of Material

	Material	Weight	Material Costs	Labor Costs	Overhead Costs	Mfg. Costs	Reference
6 Cyl. 225 CID							See sketch
Mod. Exh. Man.	-	-	-	.0625	.0250	.0875	Delta change
Heat Contl. Vlv.	Cast Iron Steel	.700	.2800	.2500	.1000	.6300	
Actuator	Steel Copper	.840	.4200	.1250	.0500	.5950	
Hardware	Steel	.050	.0100	.0010	.0004	.0114	
Connector	Rubber	.162	.0324	.0200	.0080	.0604	
Total			.7424	.4585	.1834	1.3843	
8 Cyl. 318 CID	-	-	-				
Mod. Ext. Man.	-	-	-	.0625	.0250	.0875	Delta change
Heat Contl. Vlv.	Cast Iron Steel	.600	.2400	.2400	.0960	.5760	
Actuator	Steel Copper	.650	.3250	.1250	.0500	.5000	
Hardware	Steel	.050	.0100	.0010	.0004	.0114	
Connector	Rubber	.180	.0540	.0200	.0080	.0820	
Total			.6290	.4485	.1794	1.2569	

23.2 Quick Heat Manifold

Tooling Costs

Part	Economic Volume	1 Year Recurring Tooling	3 Year Non-Recurring Tooling	12 Year Machinery and Equipment	12 Year Launching Costs	40 Year Land and Buildings	Amortization Per Piece
6 Cyl. 225 CID							
Mod. Exh. Man.	400,000	.0250 10,000	.0250 30,000	.0250 120,000	.0025 12,000	-	.0775
Heat Contl. Vlv.	1,000,000	.0200 20,000	.0200 60,000	.0400 480,000	.0040 48,000	-	.0840
Actuator	1,000,000	.0200 20,000	.0200 60,000	.0200 240,000	.0020 24,000	-	.0620
Hardware	10,000,000	.0010 10,000	.0010 30,000	.0010 120,000	.0001 12,000	-	.0031
Connector	5,000,000	.0020 10,000	.0020 30,000	.0020 120,000	.0002 12,000	-	.0062
Total							.2328
8 Cyl. 318 CID							
Mod. Exh. Man.	400,000	.0250 10,000	.0250 30,000	.0250 120,000	.0025 12,000	-	.0075
Heat Contl. Vlv.	1,000,000	.0200 20,000	.0200 60,000	.0400 480,000	.0040 48,000	-	.0840
Actuator	1,000,000	.0200 20,000	.0200 60,000	.0200 240,000	.0020 24,000	-	.0620
Hardware	10,000,000	.0010 10,000	.0010 30,000	.0010 120,000	.0001 12,000	-	.0031
Connector	5,000,000	.0020 10,000	.0020 30,000	.0020 120,000	.0002 12,000	-	.0062
Total							2328

23.3 Quick Heat Manifold

Total Manufacturing Costs

Part	Material	Labor	Overhead	Mfg. Plant Costs	Tooling		Corp. Alloc. .20VC	Corp. Profit .20VC	Mfg./ Vendor Costs
					Exp.	Inv.			
6 Cyl. 225 CID									
Mod. Exh. Man.	-	.0625	.0250	.0875	.0500	.0275	.0175	.0175	.2000
Heat Contl. Vlv.	.2800	.2500	.1000	.6300	.0400	.0440	.1260	.1260	.9660
Actuator	.4200	.1250	.0500	.5950	.0400	.0220	.1190	.1190	.8950
Hardware	.0100	.0010	.0004	.0114	0020	.0011	.0023	.0023	.0191
Connector	.0324	.0200	.0080	.0604	.0040	.0022	.0121	.0121	.0908
Total				1.3843					2.1708
8 Cyl. 318 CID									
Mod. Exh. Man.	-	.0625	.0250	.0875	.0500	.0275	.0175	.0175	.2000
Heat Contl. Vlv.	.2400	.2400	.0960	.5760	.0400	.0440	.1152	.1152	.8904
Actuator	.3250	.1250	.0500	.5000	.0400	.0220	.1000	.1100	.7720
Hardware	.0100	.0100	.0004	.0114	.0020	.0011	.0023	.0023	.0191
Connector	.0540	.0200	.0080	.0820	.0040	.0022	.0164	.0164	.1210
Total				1.2569					2.0025

23.4 Quick Heat Manifold

Retail Price Equivalent
at the Vehicle Level

Part	Vendor Costs (VC)	R&D	Tools and Equip.	Corp. Alloc. .20VC	Corp. Profit .20VC	Dealer Markup .40VC	Vehicle Retail Price Equiv.
6 Cyl. 225 CID							
Q.H. Manifold	2.1708	.3750	-	.4342	.4342	.8683	4.2824
Vehicle Assem.	.1250		-	.0250	.0250	.0500	.2250
Total							4.5074
8 Cyl. 318 CID							
Q.H. Manifold	2.0025	.3750		.4005	.4005	.8010	3.9795
Vehicle Assem.	.1250			.0250	.0250	.0500	.2250
Total							4.2045

Research & Development for 6 Cyl. & 8 Cyl.

- 150,000/year for 3 years for 400,000 cars/year or $.3750/car

23.5 Quick Heat Manifold

Cost Comparison to Aftermarket Selling Price

Using the aftermarket selling prices and the aftermarket discount data, the following analysis is made:

	AFT Selling Price	1/4 Disc.	1/5 Disc.	Vendor Costs Estimated
Heater	8.02	2.00	1.60	.9660

These comparisons illustrate the order of magnitude of the added costs for various emissions systems.

23.6 Quick Heat Manifold

Cost Methodology

The weight data and the component data was obtained from Chrysler 1975/1977 car catalogs.

The costs are estimates for mass production tooling. The costs are related to the economies of scale and the appropriate tooling investments.

23.7 Quick Heat Manifold

Applications

The engine to engine variations in design for Chrysler cars was slight. The aftermarket pricing confirms this conclusion.

The RPE estimates for:

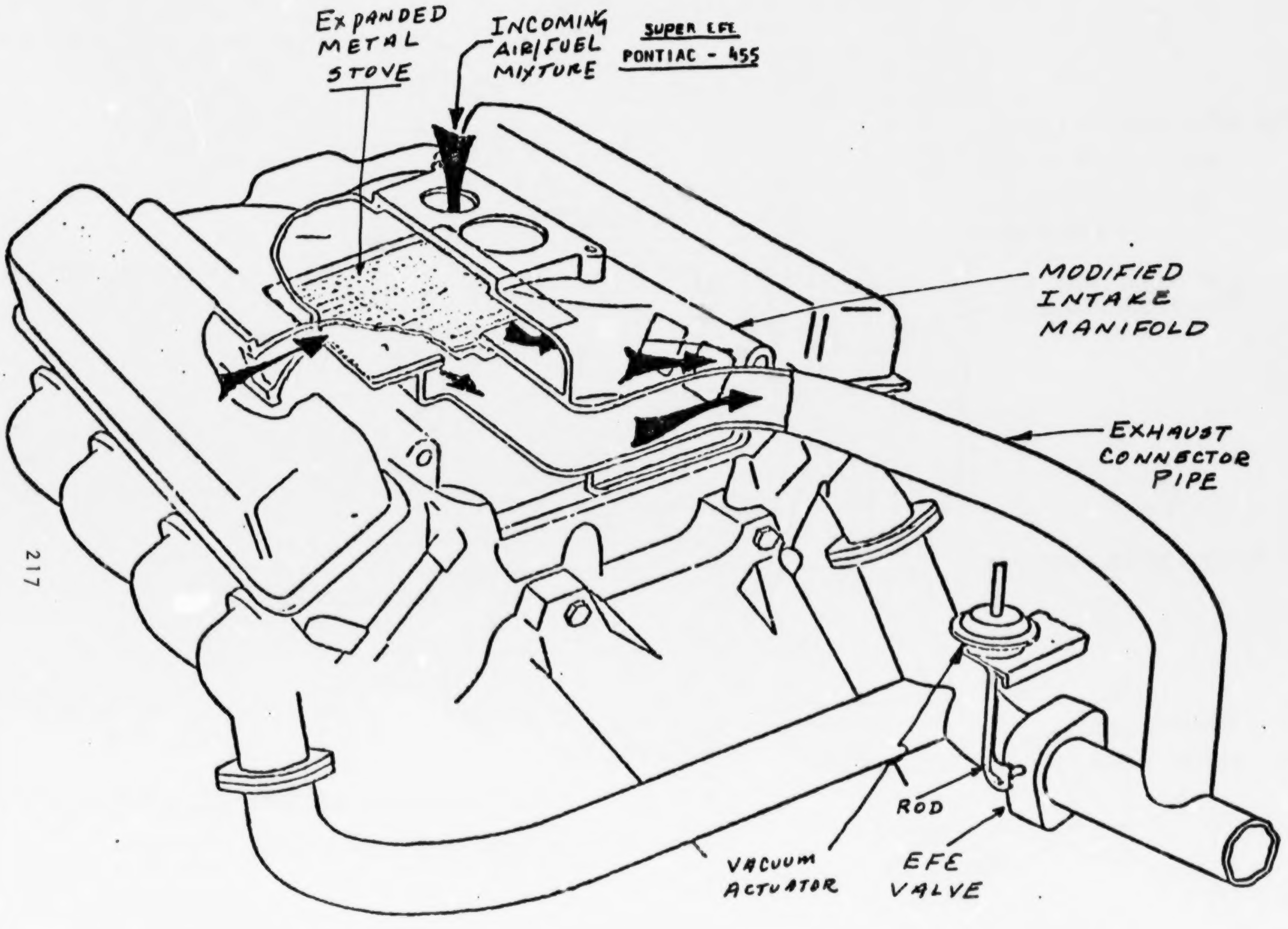
6 Cyl. 225 CID was $ 4.51
8 Cyl. 318 CID was $ 4.20

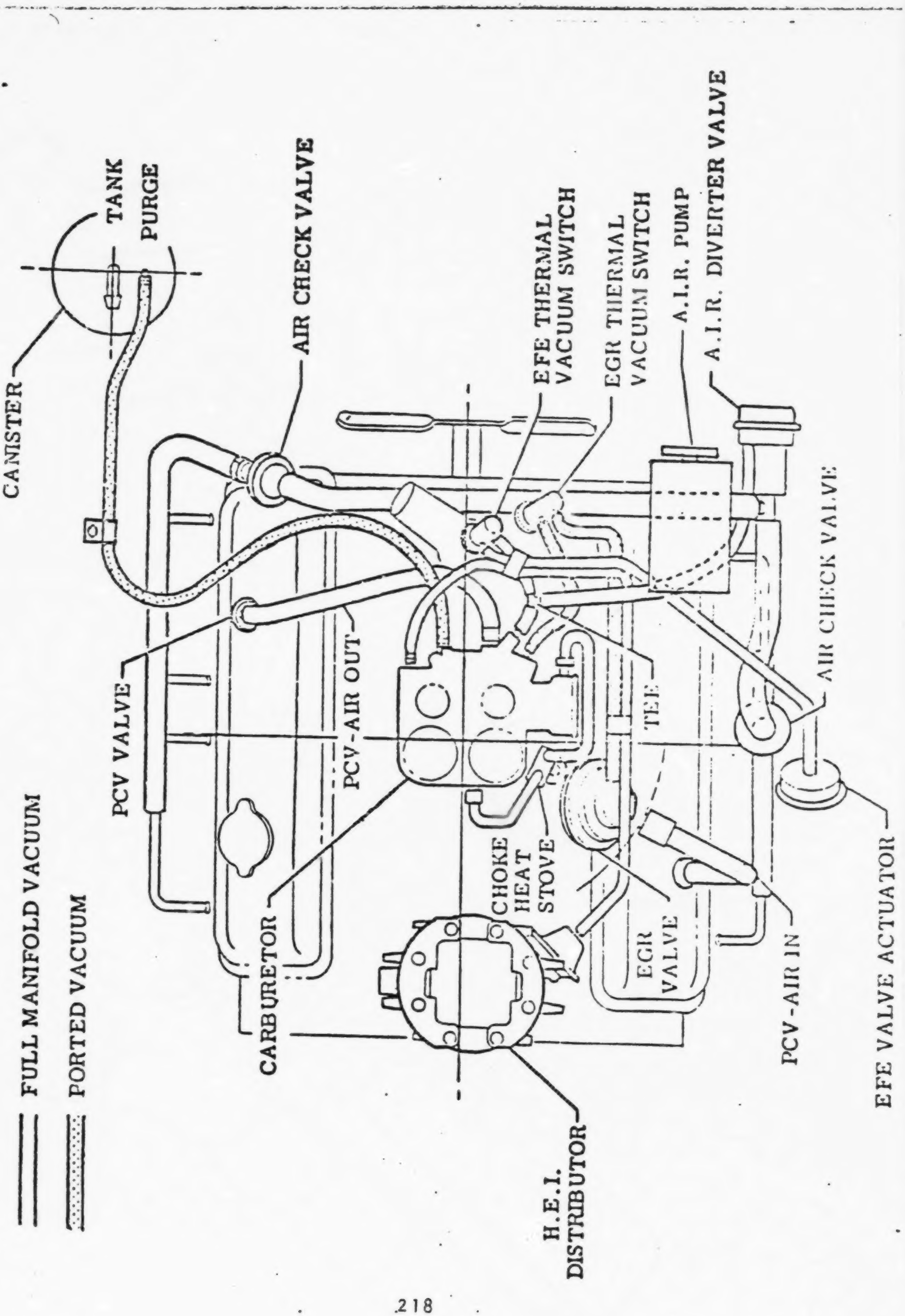
The 4-cylinder system would be proportionally less based on component weights.

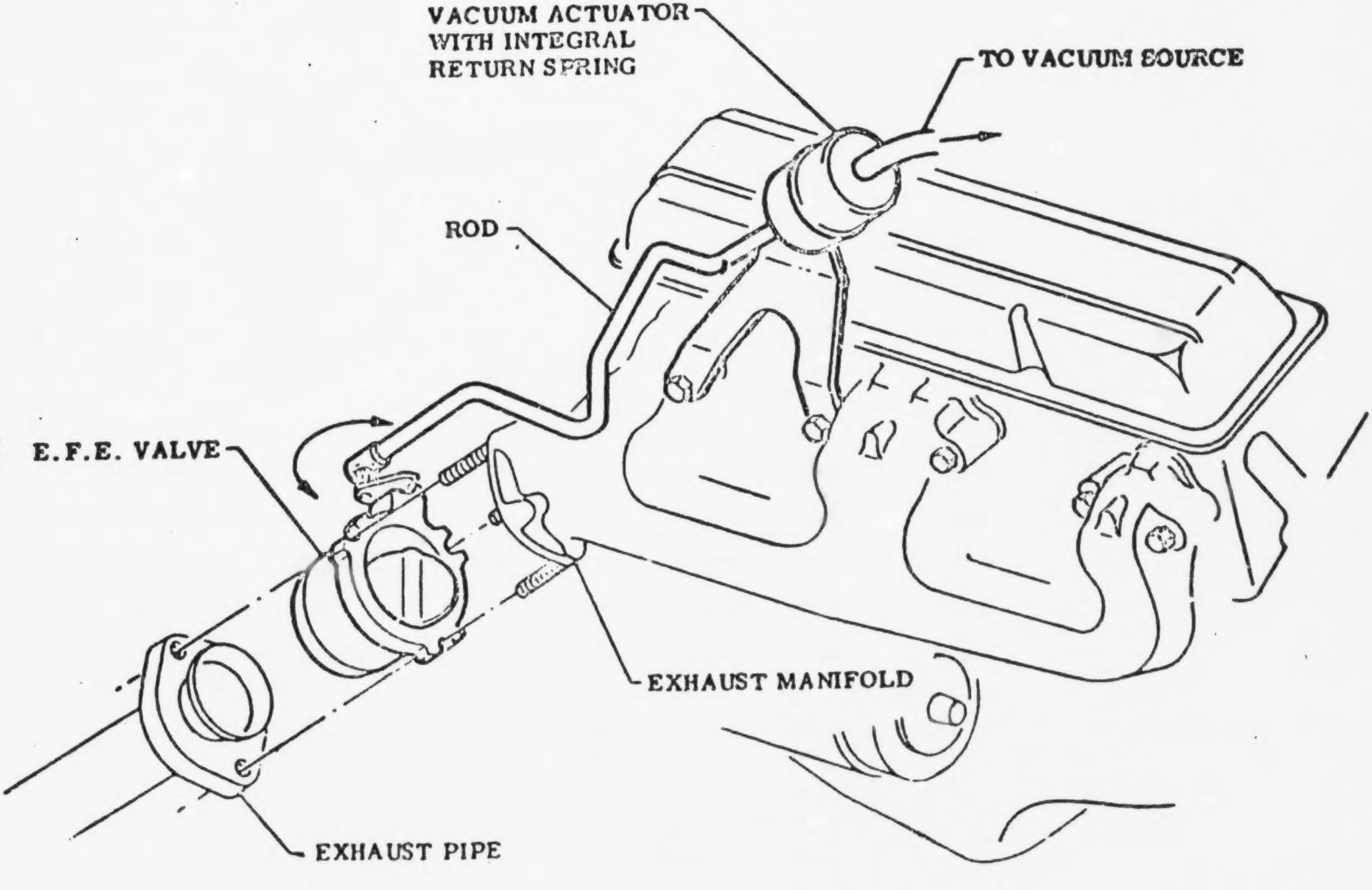
24.0 Super Early Fuel Evaporation System (SEFE)

The stringent emissions standards such as .41 HC-3.4CO-1.0NOx may require an ear fuel evaporation system during the first 2 minutes of warmup of an engine from a cold start. The catalyst system is not effective during the warmup so an added heating system is required to minimize emissions during engine warmup.

The system consists of an expanded metal stove, a vacuum actuator, and an EFE valve.


SUPER EFE
PONTIAC - 455
EXPANDED METAL STOVE
INCOMING AIR/FUEL MIXTURE
MODIFIED INTAKE MANIFOLD
EXHAUST CONNECTOR PIPE
ROD
VACUUM ACTUATOR
EFE VALVE


FULL MANIFOLD VACUUM
PORTED VACUUM
CANISTER
TANK
PURGE
AIR CHECK VALVE
PCV VALVE
PCV-AIR OUT
CARBURETOR
EFE THERMAL VACUUM SWITCH
EGR THERMAL VACUUM SWITCH
A.I.R. PUMP
A.I.R. DIVERTER VALVE
TEE
CHOKE HEAT STOVE
EGR VALVE
PCV-AIR IN
AIR CHECK VALVE
EFE VALVE ACTUATOR
H.E.I. DISTRIBUTOR


VACUUM ACTUATOR WITH INTEGRAL RETURN SPRING
TO VACUUM SOURCE
ROD
E.F.E. VALVE
EXHAUST MANIFOLD
EXHAUST PIPE

24.1 Super Early Fuel Evaporation System

Manufacturing costs

Bill of Material

Part	Material	Weight	Material Costs	Labor Costs	Labor Overhead	Manufacturing Costs	Reference
8 Cyl. 455/400 CID Mod. Intake Man.	C. I.	-	-	.2500	.1000	.3500	
Expanded Metal	Alum. Sht.	.500	.3000	.0625	.0250	.3875	
Exhaust Conn.	409SS Pipe	2.000	.8000	.1600	.0640	1.0240	
Vacuum Actuator	Steel Copper	.800	.4000	.1250	.0500	.5750	
EFE Valve	C.I. 8 STL	.700	.2800	.2500	.1000	.6300	
Hardware	Steel	.100	.0200	.0020	.0008	.0228	
Total						2.9893	
Vehicle Asm.	-	-	-	.0625	.0250	.0875	
Eng. Mod	-	-	-	.0625	.0250	.0875	
Total Vehicle						3.1643	

24.2 Super Early Fuel Evaporation System

Tooling Costs

Amortization Per Piece

Part	Economic Volume	1 Year Recurring Tooling	3 Year Nonrecurring Tooling	12 Year Machinery and Equipment	12 Year Launching Costs	40 Year Land and Building	Amortization Per Piece
8 Cyl-455 CID Mod. Int. Manif.	400,000	.0500 20,000	.0500 60,000	.0500 240,000	.0050 24,000		.1550
Expanded Metal	1,000,000	.0100 10,000	.0100 30,000	.0100 120,000	.0010 12,000		.0310
Exhaust Connector	1,000,000	.0050 5,000	.0050 15,000	.0050 60,000	.0005 6,000		.0155
Vacuum Actuator	1,000,000	.0200 20,000	.0200 60,000	.0200 240,000	.0020 24,000		.0620
EFE Valve	1,000,000	.0200 20,000	.0200 60,000	.0400 480,000	.0040 48,000		.0840
Hardware	10,000,000	.0010 10,000	.0010 30,000	.0010 120,000	.0001 12,000		.0031
SEFE - Total							.3506
Vehicle Asm.	400,000	-	-	.0083 40,000	.0008 4,000		.0092
Engine Mod	400,000	.0500 20,000	.0500 60,000	.0250 120,000	.0025 12,000		.1275
Vehicle Total							.4873

R&D - $150,000/year for 3 years for 400,000 cars/year or $.3750 each.

24.3 Super Early Fuel Evaporative System

Total Manufacturing Costs

Part	Material	Labor	Plant Overhead	Plant Mfg. Costs	Tooling Exp.	Tooling Inv.	Corp. Alloc. .20MC*	Corp. Profit .20MC*	Vendor Mfg. Costs
8 Cyl.-455 CID Mod. Int. Man.	-	.2500	.1000	.3500	.1000	.0550	.0700	.0700	.6450
Expanded Metal	.3000	.0625	.0250	.3875	.0200	.0110	.0775	.0775	.5735
Exh. Connector	.8000	.1600	.0640	1.0240	.0100	.0055	.2048	.2048	1.4991
Vacuum Actuator	.4000	.1250	.0500	.5750	.0400	.0220	.1150	.1150	.8670
EFE Valve	.2800	.2500	.1000	.6300	.0400	.0440	.1260	.1260	.9660
Hardware	.0200	.0020	.0008	.0228	.0020	.0011	.0046	.0046	.0350
Total				2.9893					4.5856

24.4 Super Early Fuel Evaporation System

Retail Price Equivalent at the Vehicle Level

Part	Plant Vendor Costs	R&D	Tools and Equip.	Corp. Alloc. .20VC*	Corp. Profit .20VC*	Dealer Markup .40VC*	Retail Price Equivalent
8 Cyl. 455 CID SEFE Sys	4.5856	.3750	-0-	.9171	.9171	1.8342	8.6291
Vehicle Asm	.0875	-	.0092	.0175	.0175	.0350	.1667
Eng. Mod.	.0875	-	.1275	.0175	.0175	.0350	.2850
Total RPE							9.0808

24.5 Super Early Fuel Evaporation System

Cost Comparison to Aftermarket Selling Prices

Using Chilton aftermarket selling price data, we compare the (GM Cadillac) following data, using aftermarket discounts.

	AFT S.P.	¼	1/5
EFE Valve	29.00	8.25	5.80
EFE Pipe	3.70	.92	.74

The EFE valve was estimated to be $.97 and the vacuum actuator is $.87. The system manufacturing costs is estimated to be $ 4.59 and the RPE is $9.08.

24.6 Super Early Fuel Evaporation System Cost Methodology

Using the sketch supplied by EPA, the unit weights were estimated by "similar to" data. The material selections are also estimates.

The tooling and manufacturing costs are based on today's technology and the optimum economy of scale.

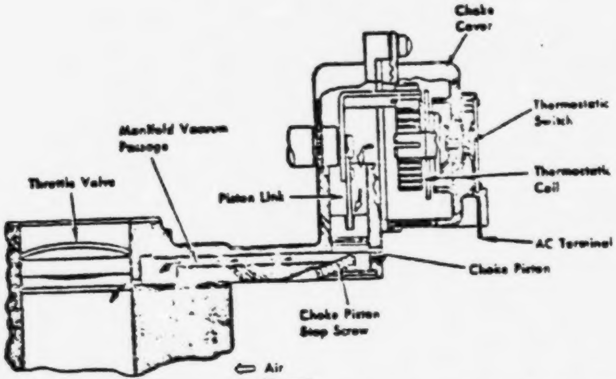
24.7 Super Early Fuel Evaporation System Applicators

The system costs will be similar for all V-8 engines. The 6 and 4 cylinder engines will probably be designed with EFE systems similar to the 23.0 systems.

25.0 Electric Heated Choke

Description of Choke

A heating element and thermostatic switch are built into the choke cover, behind the choke coil. The thermostatic switch turns on the heating element at an air temperature of approximately 80°F. The element stays on until the air temperature drops to about 65°F. The switch and heating element receive current directly from the alternator, off a special terminal that supplies about 7 volts. Because the switch and heating element are connected directly to the alternator, they only receive current when the engine is running.


Choke Cover
Thermostatic Switch
Manifold Vacuum Passage
Throttle Valve
Piston Link
Thermostatic Coil
AC Terminal
Choke Piston
Choke Piston Stop Screw
Air
Vacuum

© American Motors Corp.

The electric choke heat is in addition to the heat drawn in through a tube from the exhaust manifold stove

25.0 Electric Heated Choke

75 VL41 F24 1110.0 8 1975 VALIANT LOWLINE 4 DOOR SEDAN, (225 C.I.D.)

* U-P-G CUR=17 REV=29	Line CUR=23 REV=35	PART NO 39	DESCRIPTION 29 (OF A 3R, OR A 31 IFA NEW LINE	QTY 48	WEIGHT 55
30 BO1	100	3830576	CARB ASSY-AUTO TRANS	1	5.500
30 BO1	105	0114942	NUT	2	.020
30 BO1	116	6024844	STUD-CARB ATTG	2	.100
30 BO1	120	3698360	GASKET-CARB	1	.060
30 BO1	125	3830549	AUTO CHOKE ASSY	1	.250
30 BO1	126	2465561	CLIP-CHOKE ASSY TO CARB	1	.001
30 BO1	130	6028174	SC/W CHOKE ATTG	1	.020
30 BO1	140	3656730	CONTROL-ELEC CHOKE	1	.110
30 BO1		(SECONDARY GROUP) CARBURETOR		10	6.061

25.1 Electric Heated Choke

Manufacturing Costs

Bill of Material

Part	Material	Weight	Material Costs	Labor Costs	Labor Overhead	Manufacturing Costs	Reference
							See Sketch
EL. Choke Asm.	-	.110		.0625	.0250	.0875	
Choke Cover	Plastic	.04	.0280	.0312	.0125	.0717	
Switch	Copper	.02	.0160	.0156	.0062	.0378	
Coil	Copper	.04	.0320	.0312	.0125	.0757	
Hdw.	Stl.	.01	.0020	.0078	.0031	.0129	
Total			.0780	.1483	.0593	.2856	
Carburetor Mod.		-	-	.0625	.02500	.0875	
Total Vehicle						.3731	

25.2 Electric Heated Choke

Tooling Costs

Amortization Per Piece

Part	Economic Volume	1 Year Recurring Tooling	3 Year Nonrecurring Tooling	12 Year Machinery and Equipment	12 Year Launching Costs	40 Year Land and Building	Amortization Per Piece
El. Choke Asm	1,000,000	.0050 5,000	.0050 15,000	.0010 12,000	.0001 1,200		.0111
Choke Cover	1,000,000	.0050 5,000	.0150 45,000	.0100 120,000	.0010 12,000		.0310
Switch	1,000,000	.0020 2,000	.0020 6,000	.0020 24,000	.0002 2,400		.0062
Coil	1,000,000	.0050 5,000	.0050 15,000	.0050 60,000	.0005 6,000		.0155
Hardware	1,000,000	.0100 10,000	.0100 30,000	.0100 120,000	.0010 12,000		.0310
Vehicle Assembly	1,000,000	.0180 18,000	.0280 84,000	.0190 228,000	.0019 22,800		.0669
Carburetor Mod.	1,000,000	.0100 10,000	.0100 30,000	.0100 120,000	.0010 12,000		.0310
Total							.1927

R&D $50,000/year for 3 years for 400,000 cars/year or $.125

25.3 Electric Heated Choke

Total Manufacturing Costs

Part	Material	Labor	Plant Overhead	Plant Mfg. Costs	Tooling Exp.	Tooling Inv.	Corp. Alloc. .20MC	Corp. Profit .20MC	Vendor Mfg. Costs
El. Choke Asm.	.0780	.1483	.0593	.2856	.0640	.0308	.0571	.0571	.4946

25.4 Electric Heated Choke

Retail Price Equivalent at the Vehicle Level

Part	Plant Vendor VC	R&D	Tools and Equip.	Corp. Alloc. .20 VC	Corp. Profit .20 VC	Dealer Markup .40 VC	Vehicle Retail Price Equivalent
EL. Choke	.4946	.1250	.0669	.0989	.0989	.1979	1.0823
Carb. Mod	.0875	-	.0310	.0175	.0175	.0350	.1885
Total							1.2708

25.5 Electric Heated Choke

Cost Comparison to Aftermarket Selling Price

Using Chilton data for aftermarket selling prices

	S.P.	¼ disc	1/5
El. Heated Choke	2.22	.5550	.4440

The Estimated Mfg/Vendor cost is .4946. The RPE is 1.2708 on the vehicle which includes the carburetor modifications.

25.6 Electric Heated Choke

Cost Methodology

The weight data from Chryslers data base was used for materials cost computation. The aftermarket data was obtained from Chilton's published data. The carburetor modifications are assumed to be electric choke related only although some major casting changes were made to accommodate the electric choke assembly.

25.7 Electric Heated Choke Applications

We have assumed that the electric choke can be applied to all engine sizes without a major effect on costs.

26.0 High Energy Ignition

The high energy ignition systems are recent developments designed to improve the reliability of the ignition process in engines. These systems are installed on many recent automobile models. The system is controlled by an electronic module which is an integral part of the distributor subsystem.

The H.E.I. system utilizes an all-electronic module, pickup coil and time core in place of the conventional ignition points and condenser (the condenser is used for noise suppression only). Point pitting and rubbing block wear resulting in retarded ignition timing, is eliminated.

Since the coil is part of the H.E.I. distributor there is no need for distributor-to-coil primary (breaker points to coil negative lead) or secondary lead (high voltage lead).

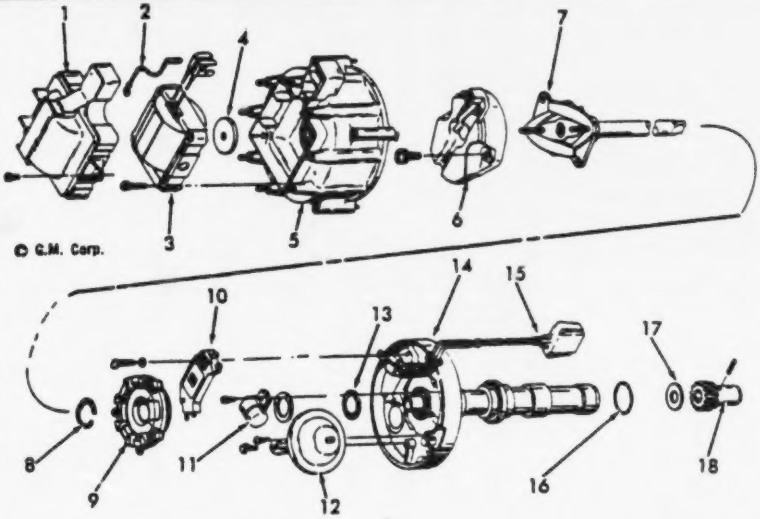
The main features of H.E.I. system differentiating this system from the "Unit Ignition" system are shown in Figures 1, 2, and 3.

The magnetic pickup consists of a rotating timer core attached to the distributor shaft, a stationary pole piece, permanent magnet and pickup coil.

When the distributor shaft rotates, the teeth of the timer core line up and pass the teeth of the pole piece inducing voltage in the pickup coil which signals the all-electronic module to open the ignition coil primary circuit. Maximum inductance occurs at the moment the timer core teeth are lined up with the teeth on the pole piece. At the instant the timer core teeth start to pass the pole teeth, the primary current decreases and a high voltage is induced in the ignition coil secondary winding and is directed through the rotor and high voltage leads to fire the spark plugs.

Group 2 - ELECTRONIC IGNITION - Parts

	Part No.	Price
Distributor Assy.		
Chevrolet		
250 eng)		
1977—w/A.T.	♦1112863	138.75
w/M.T.	♦1110666	140.00
305 eng)		
1977—exc below	1112977	170.50
Calif. w/A.T.	1112999	180.00
350 eng)		
1975-77	1112880	170.50
400 eng)		
1974—2 bbl	1112866	180.00
4 bbl	1112865	180.00
1975-76	1112882	180.00
454 eng)		
1974—2 bbl (Calif.)	1112527	170.50
1975-76	1112886	170.50
Corvette		
1975—exc below	1112888	170.50
w/Sp hi perf	1112883	180.00
Calif.	1112959	172.25
1976-77—exc below	1103200	180.00
w/A.T.	1112979	180.00
(1) Cover		
1974-77	♦1875960	3.09
(2) Lead Assy.		
1974-77	♦1876155	.58
(3) Coil		
1974-77—exc below	♦1875894	27.80
1977—250 eng	♦1115444	32.90
(4) Seal		
1974-77	♦1875962	2.51
(5) Cap		
1974-77—exc below	♦1875963	11.65
1977—250 eng	♦1880042	8.63
(6) Rotor		
1974	♦1891080	3.65
1975-77—exc below	♦1891080	3.65
1977—250 eng	♦1892562	3.90



	Part No.	Price
(7) Shaft		
Chevrolet		
(250 eng)		
1977—exc below	1891145	23.50
w/Int cyl hd	♦1891100	23.30
(w/1110166 dist)	♦1892542	25.00
(305 eng)		
1977	1892078	27.00
(350 eng)		
1975-76	830072	23.50
(400 eng)		
1974—2 bbl	1880113	23.50
4 bbl	1880115	23.50
sta wag	1876324	23.50
(454 eng)		
1974—2 bbl (Calif.)	1876404	23.50
1975-77	830121	23.50
Corvette		
1975-77—exc below	830165	23.50
Sp hi perf	830110	23.50

	Part No.	Price
1975—Calif.	1891294	23.50
1976—w/Sp hi perf		
Calif.	1891719	23.50
(8) Retainer		
Chevrolet		
1974-77	♦830446	.25
Corvette		
1975-77	N.L.	. . .
(9) Pole Piece & Plate Assy.		
1974-77	♦1875981	20.70
(10) Module		
1974-77—exc below	♦1875990	53.10
1977—250 eng	♦1880040	15.70
(11) Capacitor		
1974-77	♦1876154	2.67

	Part No.	Price
(12) Vacuum Control		
Chevrolet		
(250 eng)		
1977—exc below	♦1973550	5.50
w/Int cyl hd	♦1973517	5.85
(305, 350 engs)		
1977	♦1973517	5.85
(400 eng)		
1974—sta wag		
w/4 bbl	1973507	5.85
1975-76	1973492	5.85
(454 eng)		
1975-76	♦1973517	5.85
Corvette		
1975-77—exc below	1973482	4.48
w/Dist no.		
(1112888)	♦1973517	5.85
1976-77—350 eng (Calif.)		
w/Sp hi perf	1973508	5.85

	Part No.	Price
(13) Seal		
1974-77	♦1950569	.09
(14) Housing		
1974-77—exc below	1876222	20.25
1977—250 eng	♦1880038	14.90
(15) Harness		
1974-77—exc below	♦1876018	9.80
1977—250 eng	♦1880021	9.80
(16) Washer		
1975-77	♦1837617	.07
(17) Washer		
1974-77	♦1965864	.41
(18) Gear		
1974-77—exc below	♦1958599	5.35

	Part No.	Price
1977—250 eng		
w/Int cyl hd	♦1955676	9.00
wo/Int cyl hd	♦1962052	5.15
Ignition Wires		
Chevrolet		
(350, 400 engs)		
1974-76	♦8908551	42.75
(454 eng)		
1974 (Calif.)	8919646	43.18
1975-76	8919646	43.18
Corvette		
1975-77	8908567	45.80
Ignition Switch		
1974-77—exc below	♦1990098	6.15
tilt whl	♦1990099	6.90

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26.1 High Energy Ignition System
Manufacturing costs
Bill of Material

Part	Material	Weight	Material Costs	Labor Costs	Labor Overhead	Manufacturing Costs	Reference
Distrib. Asm.	-	2.000	-	.3500	.1400	.4900	Electronic test
Cap	Plastic	.200	.1600	.4000	.1600	.7200	See sketch
Cover	Plastic	.100	.0800	.1500	.0600	.2900	
Coil	Copper Plastic	.200	.1600	2.2500	.9000	3.3100	
Pole Pc & Plastic	Copper Iron	.100	.0800	1.2500	.5000	1.8300	
Vacuum Cont	Steel Copper	.200	.1000	.8500	.3400	1.2900	
Shaft	Steel	.3000	.1200	.7500	.3000	1.1700	
Capacitor	Plastic Copper	.1000	.5000	.5000	.2000	1.2000	
Module	Copper Plastic Ceramic	.2000	1.0000	4.0000	1.6000	6.6000	
Housing	Plastic	.4000	.3200	.7500	.3000	1.3700	
Harness	Copper	.2000	.1600	.5000	.2000	.8600	
						19.1300	

26.2 High Energy Ignition System

Tooling Costs

Amortization Per Piece

Part	Economic Volume	1 Year Recurring Tooling	3 Year Nonrecurring Tooling	12 Year Machinery and Equipment	12 Year Launching Costs	40 Year Land and Building	Amortization Per Piece
Distrib. Assem.	1,000,000	.0500 50,000	.0500 150,000	.0500 600,000	.0050 60,000		.1550
Cap	1,000,000	.0200 20,000	.0200 60,000	.0200 240,000	.0020 24,000		.0620
Cover	1,000,000	.0100 10,000	.0100 30,000	.0100 120,000	.0010 12,000		.0310
Coil	1,000,000	.0300 30,000	.0300 90,000	.0050 60,000	.0005 6,000		.0655
Pole Pc & Plate	1,000,000	.0300 30,000	.0300 90,000	.0050 60,000	.0005 6,000		.0655
Vacuum Cont	1,000,000	.0500 50,000	.0500 150,000	.0500 600,000	.0050 60,000		.1550
Shaft	1,000,000	.0200 20,000	.0200 60,000	.0100 120,000	.0010 12,000		.0510
Capacitor	1,000,000	.0100 10,000	.0100 30,000	.0100 120,000	.0010 12,000		.0310
Module	1,000,000	.0500 50,000	.0500 150,000	.1000 1,200,000	.0100 120,000		.2100
Housing	1,000,000	.0300 30,000	.0300 90,000	.0300 360,000	.0030 36,000		.0930
Harness	1,000,000	.0100 10,000	.0100 30,000	.0100 120,000	.0010 12,000		.0310
						Total	.9500

R&D 1,500,000/year for 3 years for 1,000,000 units per year or $1.50 per piece.

26.3 High Energy Ignition System

Total Manufacturing Costs

Part	Material	Labor	Plant Overhead	Plant Mfg. Costs	Tooling		Corp. Alloc. .20MC*	Corp. Profit .20MC*	Vendor Mfg. Costs
					Exp.	Inv.			
Dist. Assem.	-	.3500	.1400	.4900	.1000	.0550	.0980	.0980	.8410
Cap	.1600	.4000	.1600	.7200	.0400	.0220	.1440	.1440	1.0700
Cover	.0800	.1500	.0600	.2900	.0200	.0110	.0580	.0580	.4370
Coil	.1600	2.2500	1.9000	3.3100	.0600	.0055	.6620	.6620	4.6995
Pole Pc & Plate	.0800	1.250	.5000	1.8300	.0600	.0055	.3660	.3660	2.6275
Vacuum Cont	.1000	.8500	.3400	1.2900	.1000	.0055	.2580	.2580	1.9115
Shaft	.1200	.7500	.3000	1.1700	.0400	.0110	.2340	.2340	1.6890
Capacitor	.5000	.5000	.2000	1.2000	.0200	.0110	.2400	.2400	1.7110
Module	1.0000	4.0000	1.6000	6.6000	.1000	.1100	1.3200	1.3200	9.4500
Housing	.3200	.7500	.3000	1.3700	.0600	.0330	.2740	.2740	2.0110
Harness	.1600	.5000	.2000	.8600	.0200	.0110	.1720	.1720	1.2350
				19.1300					27.6825

26.4 High Energy Ignition System

Retail Price Equivalent at the Vehicle Level

Part	Plant Vendor Costs	R&D	Tools and Equip.	Corp. Alloc. .20VC*	Corp. Profit .20VC*	Dealer Markup .40VC*	Vehicle Retail Price Equivalent
HE Ignition	27.6825	1.5000	-	5.5365	5.5365	11.0730	51.3285

26.5 High Energy Ignition System

Cost Comparison to Aftermarket Selling Prices

The manufacturing vendor costs for the system is $ 27.6825. Using the 4 to 1 Discount the estimated aftermarket comparison price is $117.7428. The Chilton price for this system can vary between $138.75 for the 6 cylinder to $170.56 for 8 cylinder engines.

26.6 High Energy Ignition System

Cost Methodology

The weight data and material costs are estimates. The labor costs are estimates for a given economy of scale (1,000,000 units/year). The bill of material data was limited to the G.M. Chilton data.

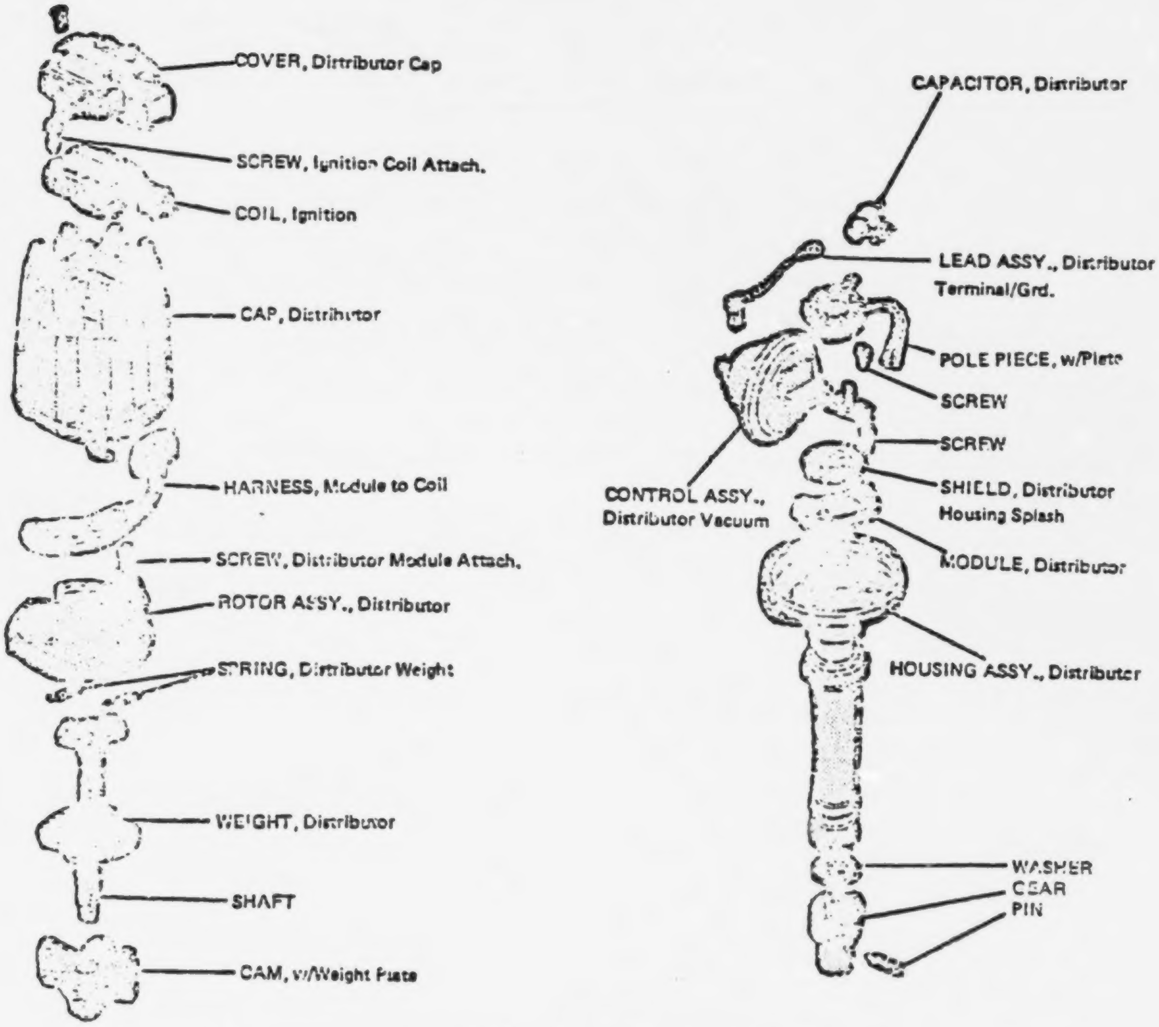
26.7 High Energy Ignition System

Applications

The applications of these costs to engines will be proportional to the number of cylinders per engines.

27.0 Breakerpoint Ignition System

The breakerpoint distributor has been the mainstay of ignition systems. The advent of the emissions requirements created the need for improved designs such as the electronic igition system defined in 26.0.


COVER, Distributor Cap
SCREW, Ignition Coil Attach.
COIL, Ignition
CAP, Distributor
HARNESS, Module to Coil
SCREW, Distributor Module Attach.
ROTOR ASSY., Distributor
SPRING, Distributor Weight
WEIGHT, Distributor
SHAFT
CAM, w/Weight Plate
CAPACITOR, Distributor
LEAD ASSY., Distributor Terminal/Grd.
POLE PIECE, w/Plate
SCREW
SCREW
SHIELD, Distributor Housing Splash
CONTROL ASSY., Distributor Vacuum
MODULE, Distributor
HOUSING ASSY., Distributor
WASHER
GEAR
PIN

Exploded view of H.E.I. distributor (Typical). All except Cadillac with fuel injection

27.1 Breakerpoint Ignition System

MANUFACTURING COSTS

Bill of Material

Part	Mat.	Weight	Mat. Costs	Labor Costs	Overhead Labor Costs	Mfg. Plant Costs
Distributor Assembly	Plastic Steel	2.000	1.000	2.800	1.1200	4.9200
Cap	Plastic	.150	.1200	.3500	.1400	.6100
Rotor	Plastic Copper	.050	.0100	.1000	.0400	.1500
Breakerpoints	Copper	.010	.0080	.1200	.0480	.1760
Condenser	Plastic Copper	.050	.0400	.1100	.0440	.1940
Vacuum Control	Steel Copper	.200	.1000	.3500	.1400	.5900
Ignition Coil	Copper Plastic	1.780	1.0680	.7500	.3000	2.1180
Total						8.7580

27.2 Breakerpoint Ignition System

TOOLING COSTS

Amortization per Piece

Part	Economic Volume Per Year	1-Year Recurring Tooling	3-Year Non Recurring Tooling	12-Year Machinery Equipment	12-Year Launching Costs	40-Year Land & Buildings	Amortization Per Piece
Distributor Assembly	1,000,000	.0500 50,000	.0500 150,000	.0500 600,000	.0050 60,000	--	.1550
Cap	1,000,000	.0100 10,000	.0100 30,000	.0100 120,000	.0010 12,000	--	.0310
Rotor	1,000,000	.0050 5000	.0100 30,000	.0050 60,000	.0005 6000	--	.0205
Breakerpoints	1,000,000	.0050 5000	.0100 30,000	.0050 60,000	.0005 6000	--	.0205
Condenser	1,000,000	.0300 30,000	.0300 90,000	.0050 60,000	.0005 6000	--	.0655
Vacuum Contl	1,000,000	.0300 30,000	.0300 90,000	.0050 60,000	.0005 6000	--	.0655
Ignition Coil	1,000,000	.0300 30,000	.0300 90,000	.0050 60,000	.0005 6000	--	.0655
Total							.4235

27.3 Breakerpoint Ignition System

TOTAL MANUFACTURING COSTS

Part	Mat	Labor	Plant Over-Head	Plant Mfg Costs (MC)	Tooling		.20/MC Corp. Alloc.	.20/MC Corp. Profit	Mfg Ven Cos
					Exp.	Inv.			
Dist. Assembly	1.000	2.8000	1.1200	4.9200	.1000	.0550	.9840	.9840	7.04
Cap	.1200	.3500	.1400	.6100	.0200	.0110	.1220	.1220	.88
Rotor	.0100	.1000	.0400	.1500	.0150	.0055	.0300	.0300	.23
Breaker Points	.0080	.1200	.0480	.1760	.0150	.0055	.0352	.0352	.26
Condenser	.0400	.1100	.0440	.1940	.0600	.0055	.0388	.0388	.33
Vacuum Coil	.1000	.3500	.1400	.5900	.0600	.0055	.1180	.1180	.89
Ignition Coil	1.0680	.7500	.3000	2.1180	.0600	.0055	.4236	.4236	3.03
Total				8.7580					12.68

27.4 Breakerpoint Ignition System

RETAIL PRICE EQUIVALENT AT THE VEHICLE LEVEL

	Vendor Costs (VC)	R&D	Tools and Equip	Corp Allocation .20 VC	Corp Profit .20 VC	Dealer Markup .40 VC	Vehicle Retail Price Equiv.
Dist. System	12.6847	--	--	2.5369	2.5369	5.0739	22.8325
Vehicle Assy	.2500	--	--	.0500	.0500	.1000	.4500
Total RPE							23.2825

27.5 Breakerpoint Ignition System

Group 2 (Chilton)
Ignition System (Chrysler data)
Aftermarket Selling Price Analysis

	Breakerless Distribution Assembly 1972 Data	High Energy Ignition 1977 Data Total Assembly
Six Cyl	39.80	45.00
8 Cyl 318	46.25	47.55
8 Cyl 400	53.15	54.75

	1972 6 Cyl	1972 8 Cyl	1977 6 Cyl	1977 8 Cyl
Distribution Cap	4.25	4.85	3.81	4.85
Points	3.30	3.30	--	--
Condenser	1.60	1.60	--	--
Dist Lead Wires	.82	.82	--	--
Rotor	1.25	1.25	1.92	1.92
Reluctor	--	--	1.92	1.92
Pick up and Plate	--	--	13.45	13.45
Breaker Plates	10.50	10.50	--	--
Vacuum Control Unit	5.35	5.35	5.35	5.35
Coil	14.92	14.92	--	--
Resistors	2.55	2.55	--	--
Governor Shaft Assembly	14.95	14.95	14.95	14.95
Dist Housing	6.07	8.69	6.07	8.69

27.5 Breakpoint Ignition System
Analysis of Aftermarket Selling Prices
Group 2 (Chilton) G. M. Data

Breakerless Assembly (1972 car data)			Electronic Ignition (1977 car data)		
	6 Cyl	8 Cyl		6 Cyl	8 Cyl
Distributor Assembly	54.05	58.30	(Total Distributor)	138.75	170.50
Points	3.68	5.60		-	-
Condenser	1.71	1.71		-	-
Rotor	1.35	2.31		3.65	3.90
Cap	4.07	6.55	Cap Cover	8.63 3.09	11.65 3.09
Coil	16.40	16.40	Coil	32.90	27.80
Breaker Plate	3.00	3.29	Pole Piece & Plate	20.70	20.70
Vacuum Control	4.02	4.02		5.85	5.85
Shaft (Included in Assy.)	23.50	23.50		23.50	23.50
Capacitor	-	-		2.67	2.67
Module	-	-		15.70	53.10
Housing	Included Item 1			14.90	20.25
Harness	-	-		9.80	9.80
Total	111.78	121.68			
Less Shaft	23.50	23.50			
	88.28	98.18		138.75	170.50

27.6 Breakerpoint Ignition System

COST METHODOLOGY

The weight data was obtained from Chrysler data. The cost estimates are gross; not based on a part by part operational analysis.

The analysis of various systems--breakerpoint versus electronic--provides a top down reference cost.

27.7 Breakerpoint Ignition System

APPLICATIONS

Using the aftermarket data, the delta difference by engine size is proportional to the number of cylinders.

28.0 Stainless Steel Exhaust System For 6-Cylinder 225 CID and 8-Cylinder 318 CID Engines

Using the exhaust systems shown in Section 29.0, we assumed that the exhaust pipe would be changed to stainless steel.

The computations were made for the exhaust pipe sections only.

28.1 Exhaust System--Stainless Steel--Bill of Material

MANUFACTURING COSTS

CID 225 - 6 CYLINDER

	Part	Weight	Type Material	Material (+35%)	$ Labor	$ O.H.	$ Mfg. Cost
1.	Exhaust Pipe	6.90	S. Steel	$ 7.27	$ .30	$.12	$ 7.69
2.	Extension Pipe	3.00	Alum. Steel	.98	.18	.07	1.23
3.	Brackets, Clamps	.80	Steel	.20	.09	.03	.32
4.	Hardware	.22	Steel	.05	.07	.03	.15
7.	Muffler	9.22	Steel	2.30	.86	.35	3.51
8.	Brackets, Clamps	.32	Steel	.08	.07	.03	.18
9.	Hardware	.09	Steel	.02	.06	.03	.11
10.	Tail Pipe	5.00	Alum. Steel	1.63	.24	.10	1.97
11.	Brackets, Clamps	1.63	Steel	.41	.11	.05	.57
12.	Hardware	.07	Steel	.02	.06	.02	.10
	Totals	27.25		$12.96	$2.04	$.83	$15.83

Stainless Steel $.78 + 35% Loss

All Items Except #1 From Steel Exhaust

28.1 Exhaust System--Stainless Steel--Bill of Material

MANUFACTURING COSTS

CID 318 - 8 CYLINDER

	Part	Weight	Type Material	Material (+35%)	$ Labor	$ O.H.	$ Mfg. Cost
1.	Exhaust Pipe	12.19	S. Steel	$12.84	$ .46	$ .18	$13.48
2.	Extension Pipe	3.00	Alum. Steel	.98	.18	.07	1.23
3.	Brackets, Clamps	.41	Steel	.10	.07	.03	.20
4.	Hardware	.64	Steel	.16	.08	.03	.27
7.	Muffler	10.99	Steel	2.74	1.01	.41	4.16
8.	Brackets, Clamps	.66	Steel	.16	.09	.03	.28
9.	Hardware	.24	Steel	.06	.06	.03	.15
10.	Resonator	5.30	Steel	1.32	.54	.22	2.08
11.	Tail Pipe	5.00	Alum. Steel	1.63	.24	.10	1.97
12.	Brackets, Clamps	1.88	Steel	.47	.12	.05	.64
13.	Hardware	.03	Steel	.01	.06	.02	.09
	Totals	40.32		$20.47	$2.91	$1.17	$24.55

Stainless Steel $.78 + 35%

All Items Except #1 From Steel Exhaust

28.2 Stainless Steel Exhaust System for 6-Cylinder 225 CID and 8-Cylinder 318 Engines

TOOLING AMORTIZATION

Part	Economic Volume Per Year	1 Year Recurring Tooling	3 Year Non-Recurring Tooling	12 Year Machinery Equipment	12 Year Launching Costs	40 Year Land & Buildings	Amortization Per Piece
6 Cylinder							
		.0500	.0500	.0100	.0010		.1110
Exhaust Pipe	1,000,000	50,000	150,000	120,000	12,000	-	
8 Cylinder							
		.0500	.0500	.0100	.0010		.1110
Exhaust Pipe	1,000,000	50,000	150,000	120,000	12,000	-	

28.3 Stainless Steel Exhaust System

TOTAL MANUFACTURING COSTS
FOR 6 AND 8-CYLINDER ENGINES

Part	Mat	Labor	Plant Over-Head	Plant Mfg Costs (MC)	Tooling Exp.	Tooling Inv.	.20/MC Corp Costs	.20/MC Corp Profit	Mfg/ Vendo Costs
6 Cylinder									
Exhaust Pipe	7.27	.3000	.1200	7.6900	.1000	.0110	1.5380	1.5380	10.87
8 Cylinder									
Exhaust Pipe	12.84	.4600	.1800	13.4800	.1000	.0110	2.6960	2.6960	18.98

28.4 Stainless Steel Exhaust System

RETAIL PRICE EQUIVALENT
AT THE VEHICLE LEVEL

Part	Plant Vendor Costs (VC)	R&D	Tools and Equip	Corp Allocation .20 VC	Corp Profit .20 VC	Dealer Markup .40 VC	Vehicle Retail Price Equivalent
6 Cylinder							
Exhaust Pipe	10.8770	-	-	2.1754	2.1754	4.3508	19.5786
8 Cylinder							
Exhaust Pipe	18.9830	-	-	3.7966	3.7966	7.5932	34.1694

No vehicle assembly or engine modification added costs are incurred.

28.5 Stainless Steel Exhaust System Cost Comparison to Aftermarket Selling Prices

No aftermarket data were available for a stainless steel exhaust system, so we assumed a 4 times multiplier over our vendor costs.

	Vendor Costs	Estimated Aftermarket Selling Price
6-Cylinder Exhaust Pipe	10.8770	43.5080
8-Cylinder Exhaust Pipe	18.9830	75.9320

These estimates are about 2 times the equivalent carbon steel prices.

28.6 Stainless Steel Exhaust System Cost Methodology

The cost methodology is explained in Section 29.6. For this section, we assumed the exhaust pipe section between engine and catalytic converter to be made of stainless steel.

28.7 Stainless Steel Exhaust System Applications

The costs were computed for two typical Chrysler systems. It is assumed that other 6- and 8-cylinder exhaust system costs will be similar.

29.0 Standard Steel Exhaust System

The standard exhaust system for 225 CID 6-cylinder and 318 CID 8-cylinder engines is illustrated in the attached sketches. The introduction of catalysts at various locations in automobiles has made the analysis complicated. Therefore, a typical system was chosen so that all the related components could be identified. Chrysler data were used throughout so that a consistent format was evident.

29.1 Standard Steel Exhaust System

BILL OF MATERIAL - MANUFACTURING COSTS

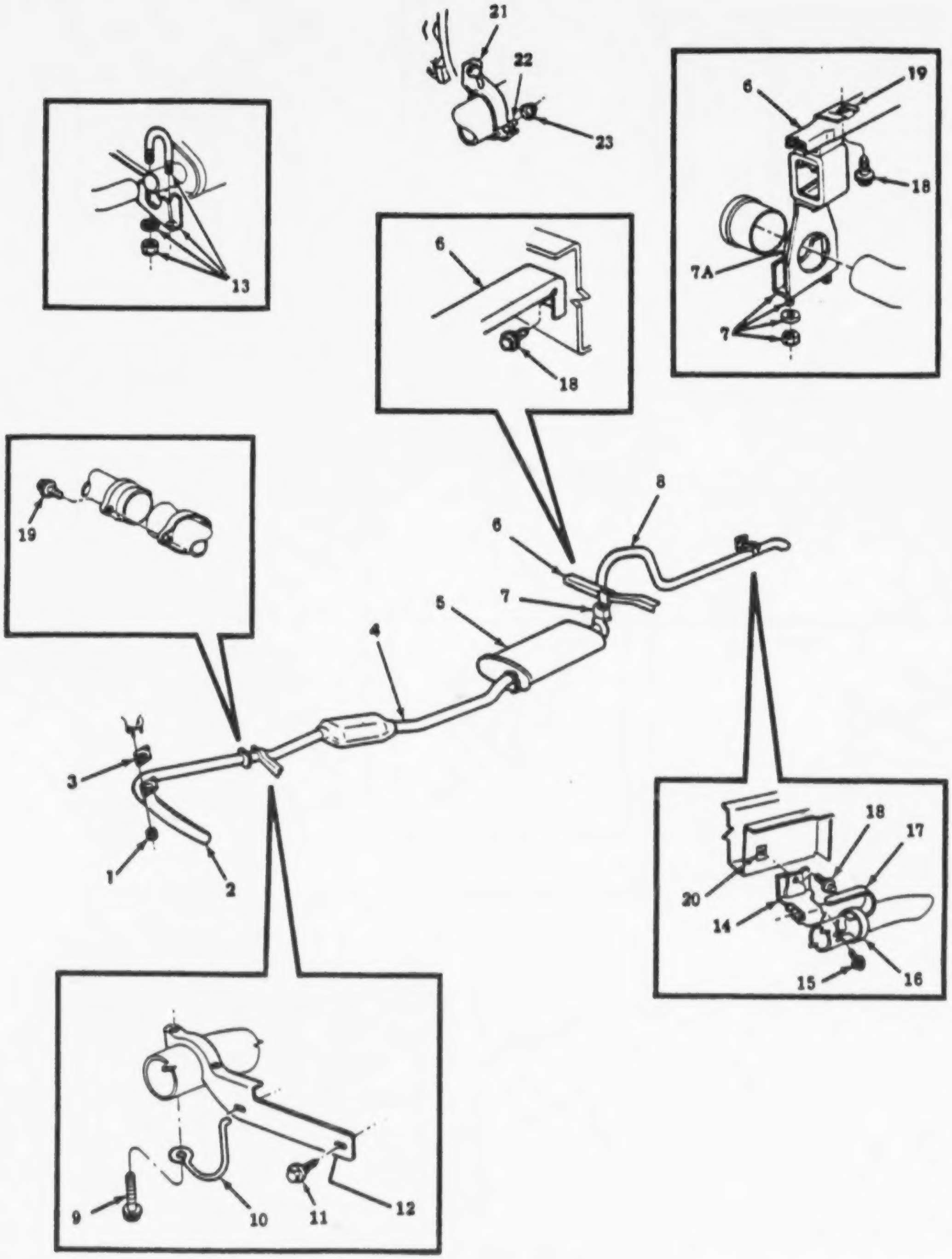
225 C.I.D. - 6 CYLINDER

		Weight	Type Material	+ 35% $ Material	$ Labor	$ O.H.	$ Mfg. Cost	
1	Exh. Pipe	6.90	Alum. Steel	2.24	.30	.12	2.66	Complex
2	Exten. Pipes	3.00	Alum./Steel	.98	.18	.07	1.23	Complex
3	Brkts, Clamps (2)	.80	Steel	.20	.09	.03	.32	Medium
4	Hardware	.22	Steel	.05	.07	.03	.15	Medium
	Subtotal			3.47	.64	.25	4.36	
5	Cat. Converter							
6	Hardware							
7	Muffler	9.22	Steel	2.30	.86	.35	3.51	Complex
8	Brkts, Clamps (1)	.32	Steel	.08	.07	.03	.18	Medium
9	Hardware	.09	Steel	.02	.06	.03	.11	Medium
	Subtotal			2.40	.99	.41	3.80	
10	Tail Pipe	5.00	Alum. Steel	1.63	.24	.10	1.97	Complex
11	Brkts, Clamps (2)	1.63	Steel	.41	.10	.04	.56	Medium
12	Hardware	.07	Steel	.02	.06	.02	.10	Medium
	Subtotal			2.06	.41	.16	2.63	
	TOTALS	27.25		7.93	2.04	.82	10.79	

2792 Aluminized Steel @ .2112 @ 65% Yield = $.325 Per Pound Finished Part
Cold Rolled Steel @ .1616 @ 65% Yield = $.249 Per Pound Finished Part

Complex Stamp Steel Formula Manufacturing Cost = (lbs. x .367) + .13
Medium Stamp Steel Formula Manufacturing Cost = (lbs. x .30) + .08
Simple Stamp Steel Formula Manufacturing Cost = (lbs. x .233) + .03

7111200 EXHAUST SYSTEM - R, W, -225 ENGINE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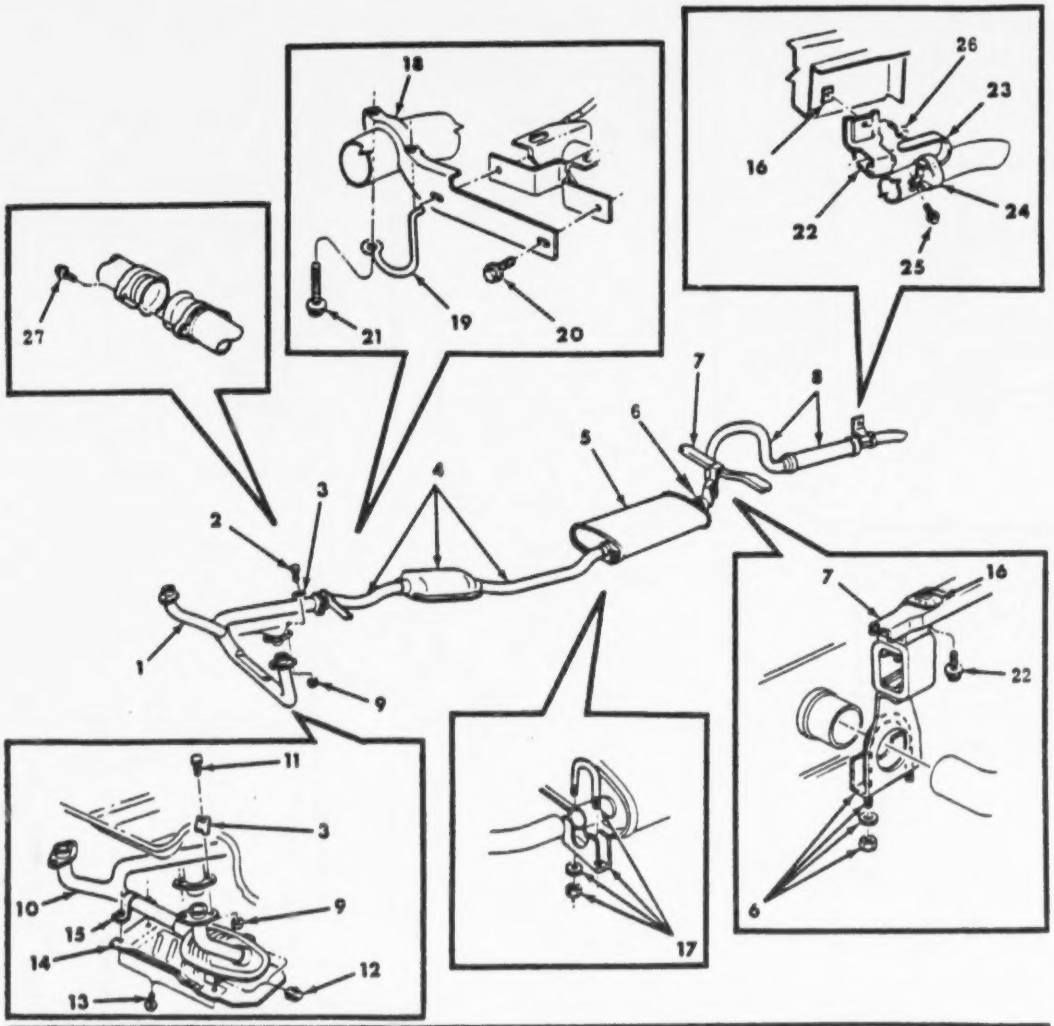
1977 PASSENGER CAR PARTS CATALOG

7111300 EXHAUST SYSTEM - SINGLE - R, W, X, S - 318, 360, 400 ENGINE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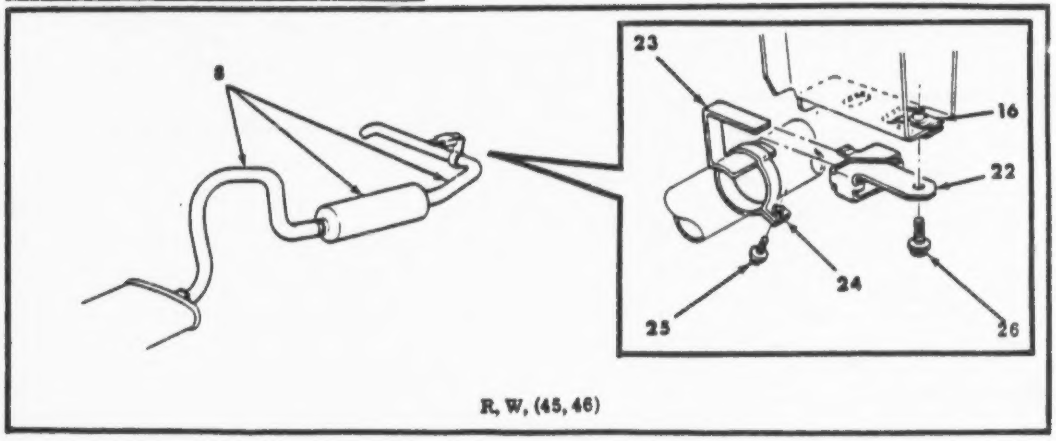
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29.1 Bill of Material

C 75 VL41 E24 111.0 B 1975 Valiant Lowline 4-Door Sedan, (225 C.I.D. 6 Cylinder)

U-P-G Cur=17 Rev=29	Line Cur=23 Rev=35	Part No. 39	Description 29 (Of a 3R, or a 31, If a New Line)	Quantity 48	Weight 55
36E01	135	4004164	Shield Assembly-Heat Converter Extension	1	.900
36E01	140	6022258	Screws and Washer-Bracket Attachments--Right	2	.100
36E01	141	4004003	Bracket	1	.700
36E01	145	4004170	Strap-Ht/Shoulder Support	1	.070
36E01	150	0152941	Screws and Washers	2	.060
36E01	155	0152796	Screws	2	.040
36E01	160	4004049	U-Bolt-Exhaust Pipe	1	.080
36E01	165	4004050	U-Bolt	1	.090
36E01	210	3818180	Muffler	1	9.220
36E01	220	4004141	Converter-Catalytic	1	10.087
36E01"			(Secondary Group) Exhaust Pipe	16	20.323
36E02	200	3726635	Pipe Assembly-Exhaust	1	6.900
36E02	204	6024343	Nut-Exhaust Pipe to Manifold	2	.060
36E02	206	2465391	Gasket-Exhaust Pipe	1	.030
36E02	225	2823900	Saddle Clamp Assembly-Muffler Tail Pipe	1	.320
36E02"			(Secondary Group) Muffler	5	7.310
36E03	300	3642491	Tail Pipe Assembly	1	5.000
36E03	305	3642500	Bracket Assembly-Tail Pipe	1	.460
36E03	315	6030466	Screw Tapping	1	.030
36E03	350	2823455	Insulator Assembly-Tail Pipe Front Complete	1	1.170
36E03	355	0152274	J Nut-Support Mtg	1	.010
36E03	360	6022226	Bolt-Support Mtg.	1	.030
36E03"			(Secondary Group) Tail Pipe Including Resonator	6	6.700
36E03"			(Primary Group) Exhaust System	27	34.333
36E01	125	2925639	Clamp-Exhaust Pipe Front	1	.100
36E01	130	6027865	Screws and Washers	2	.116

29.1 Standard Steel Exhaust System

BILL OF MATERIAL - MANUFACTURING COSTS

318 CID - 8 cylinder

		Weight	Type Material	$ Material	$ Labor	$ O.H.	Cost	$ Mfg
1.	Exhaust Pipe	12.185	Alum/Steel	3.96	.46	.18	4.60	Complex
2.	Extension Pipe	3.00	Alum/Steel	.98	.18	,07	1.23	Complex
3.	Brackets, clamps	.41	Steel	.10	.07	.03	.20	Medium
4.	Hardware	.64	Steel	.16	.08	.03	.27	Medium
	Subtotal			5.20	.79	.31	6.30	
7.	Muffler	10.985	Steel	2.74	1.01	.41	4.16	Complex
8.	Brackets, clamps	.66	Steel	.16	.09	.03	.28	Medium
9.	Hardware	.236	Steel	.06	.06	.03	.15	Medium
	Subtotal			2.96	1.16	.47	4.59	
10.	Resonator	5.30	Steel	1.32	.54	.22	2.08	Complex
11.	Tail Pipe	5.00	Alum Steel	1.63	.24	.10	1.97	Complex
12.	Brackets, clamps	1.88	Steel	.47	.12	.05	.64	Medium
13.	Hardware	.03	Steel	.01	.06	.02	.09	Medium
	Subtotal			2.11	.42	.17	2.70	
	Totals	40.32		11.59	2.91	1.17	15.67	

29.1 Standard Steel Exhaust System

C 75 VL41 L44 111.0 B 1975 Valiant Lowline 4-Door Sedan, (318 CID V-8BBL)

U-P-G-	Line	Part No.	Description	Quantity	Weight
Cur=17	Cur=23	39	19 (of a 3R, or a 31 if a new line)		
Rev=29	Rev=35				
36E01	105	3726865	Pipe Assembly - Exhaust	1	12.185
36E01	110	0180132	Bolt	4	.320
36E01	115	4004001	Ret	4	.040
36E01	120	9423837	Nut-Ex Pipe to Manifold	4	.100
36E01	125	2823906	U-Bolt and Saddle Assembly - Tail Pipe	1	.410
36E01	135	2823456	Insulator Assembly - Tail Pipe Frt Complete	1	1.170
36E01	140	6022226	Bolt-Support Mtg	1	.030
36E01	150	4004009	Heat Shield .065	1	2.20
36E01	155	0152470	Nut	4	.040
36E01	160	4004164	Shield Assembly - Heat Conv Ext	1	.900
36E01	175	4004171	Strap	1	.080
36E01	175	0152796	Screw	2	.040
36E01	180	4004050	U-Bolt	2	.180
36E01	185	3906433	Convertor-Cata Assembly	1	14.500
36E01		(Secondary Group) Exhaust Pipe		28	27.735

29.1 Standard Steel Exhaust System

C 75 VL41 L44 111.0 B 1975 Valiant Lowline 4-Door Sedan, (318 CID V-8BBL)

U-P-G-	Line	Part No.	Description	Quantity	Weight
Cur=17	Cur=23	39	19 (of a 3R, or a 31 if a new line)		
Rev=29	Rev=35				
36E02	205	3728997	Muffler	1	10.985
36E02	210	6022258	SC&WA - Bracket Attg-Rt	2	.100
36E02	215	2925639	Clamp-Ex Pipe Frt	1	.100
36E02	220	0152941	SC&WA	2	.060
36E02	225	2823456	Insulator Assembly-Tail pipe Frt Complete	1	1.170
36E02	230	6022226	Bolt - Support Mtg	2	.060
36E02	235	6C2/865	SC&WA	2	.116
36E02	240	3642500	Bracket Assembly - Tail Pipe	1	.460
36E02		(Secondary Group) Muffler		12	13.051

29.1 Standard Steel Exhaust System

C 75 VL41 L44 111.0 B 1975 Valiant Lowline 4-Door Sedan, (318 CID V-8BBL)

U-P-G-	Line	Part No.	Description	Quantity	Weight
Cur=17	Cur=23	39	19 (of a 3R, or a 31 if a new line)		
Rev=29	Rev=35				
36E03	300	3818161	Pipe Assembly - With Resonator	1	10.300
36E03	305	4004003	Bracket	1	.700
36E03	310	0152274	J Nut- Support Mtg	1	.010
36E03	315	6030466	Screw Tapping	1	.030
36E03			(Secondary Group) Tailpipe including Resonator	4	11.040
			(Primary Group) Exhaust System	44	51.826

29.2 Standard Steel Exhaust System for 225 CID and 318 CID Engines

TOOLING COSTS

Part	Economic Volume Per Year	1-Year Recurring Tooling	3-Year Non Recurring Tooling	12-Year Machinery Equipment	12-Year Launching Costs	40-Year Land & Buildings	Amortization Per Piece
Exhaust Pipes	1,000,000	.0250 25,000	.0250 75,000	.0050 60,000	.0005 6000		.0555
Extension Pipes	2,000,000	.0125 25,000	.0100 60,000	.0025 60,000	.0002 6000		.0252
Brackets, clamps	2,000,000	.0025 5000	.0050 30,000	.0015 36,000	.0002 3600		.0092
Hardware	10,000,000	.0050 50,000	.0050 150,000	.0010 120,000	.0001 12,000		.0111
Sub total		.0450	.0450	.0100	.0010		.1010
Muffler	2,000,000	.0250 50,000	.0250 150,000	.0500 1,200,000	.0050 120,000	--	.1050
Brackets	2,000,000	.0025 5000	.0050 30,000	.0015 36,000	.0002 3600	--	.0092
Hardware	10,000,000	.0050 50,000	.0050 150,000	.0010 120,000	.0001 12,000	--	.0111
Subtotal		.0325	.0350	.0525	.0053		.1253
Tail pipe	1,000,000	.0250 25,000	.0200 60,000	.0050 60,000	.0005 6000	--	.0505
Brackets	2,000,000	.0025 5000	.0050 30,000	.0015 36,000	.0002 3600	--	.0092
Hardware	10,000,000	.0050 50,000	.0050 150,000	.0010 120,000	.0001 12,000	--	.0111
Subtotal		.0325	.0300	.0075	.0008		.0708
Vehicle Assembly	300,000	--	--	--	--	--	--
Total							.2971

R&D estimates - $100,000/year for 1,000,000/year or .10 per vehicle.

29.3 Standard Steel Exhaust System

TOTAL MANUFACTURING COSTS

for 6-Cylinder - 225 CID

Part	Mat	Labor	Plant Over-Head	Plant Mfg Costs (MC)	Tooling Exp.	Tooling Inv.	.20/MC Corp. Costs	.28/MC Corp. Profit	Mfg/ Vendor Costs
Exhaust and Ext.	3.4700	.6400	.2500	4.3600	.0900	.0110	.8720	.8720	6.2050
Muffler	2.4000	.9900	.4100	3.800	.0675	.0578	.7600	.7600	5.4453
Tail Pipe	2.0600	.4100	.1700	2.63	.0625	.0083	.5260	.5260	3.7528
Totals	7.9300	2.0400	.8300	10.79					15.4031

for 8-Cylinder - 318 CID

Part	Mat	Labor	Plant Over-Head	Plant Mfg Costs (MC)	Tooling Exp.	Tooling Inv.	.20/MC Corp. Costs	.28/MC Corp. Profit	Mfg/ Vendor Costs
Exhaust	4.2000	.7900	.3100	6.3000	.0900	.0110	1.2600	1.2600	8.9210
Muffler	2.9600	1.0600	.4700	4.5900	.0675	.0578	.9180	.9180	6.5513
Resonator	1.3200	.5400	.2200	2.0800	.0675	.0578	.4160	.4160	3.0373
Tail Pipe	2.1100	.4200	.1700	2.7000	.0625	.0083	.5400	.5400	3.8508
Totals	11.5900	2.9100	1.1700	15.6700					22.3604

29.4 Standard Steel Exhaust System

RETAIL PRICE EQUIVALENT AT THE VEHICLE LEVEL

Part	Vendor Costs (VC)	R&D	Tools and Equip	Corp Allocation .20 VC	Corp Profit .20 VC	Dealer Markup .40 VC	RPE Vehicle Level
6 Cylinder							
Exhaust	6.2050	.10	--	1.2410	1.2410	2.4820	11.2690
Muffler	5.4453		--	1.0891	1.0891	2.1781	9.8015
Tail Pipe	3.7528		--	.7506	.7506	1.5011	6.7550
Vehicle Assembly	.1250		--	.0250	.0250	.0500	.2250
Total	15.5281						28.0505
8 Cylinder							
Exhaust	8.9210	.10	--	1.7842	1.7842	3.5684	16.1578
Muffler	6.5513		--	1.3103	1.3103	2.6205	11.7923
Resonator	3.0373		--	.6075	.6075	1.2149	5.4671
Tail Pipe	3.8508		--	.7702	.7702	1.5403	6.9314
Vehicle Assembly	.2500		--	.0500	.0500	.1000	.4500
Total	22.6104						40.7986

No additional costs for engine modification.

29.5 Standard Steel Exhaust System

COST COMPARISON TO AFTERMARKET SELLING PRICES USING FURY (1975) 318 CID ENGINE DATA

Part	Part No.	S.P.	1/4 S.P.	Vendor Costs	RPE
Muffler	21848	27.25	6.81	6.5513	11.7923
Tail Pipe	43633	9.69	2.42	3.8610	6.9314
Tail PIpe	41206	4.86	1.21		
Resonator	21852	17.53	4.38	3.0373	5.4671

The vendor costs include clamps and hardware.

29.6 Cost Methodology

BASES FOR MANUFACTURING COST ESTIMATIONS
250 and 318 CID EXHAUST SYSTEMS

1. Sketches of exhaust systems (11-6 and 11-9)

2. B.O.M. 1975 Valiant; 250 CID, 6-cylinder, 318 CID, 8-Cylinder (computer printout) insulator assemblies (catalytic converter omitted).

3. Weights given on B.O.M. used in "stamped steel" formulae (from Pioneer data analysis) to get manufacturing cost.

   "complex" formula - manufacturing cost = (.367 x weight) + .13 used on pipes, mufflers, resonator.

   "medium" formula - manufacturing cost = (.300 x weight) + .08 used on other parts.

   (The applicability of formulae were checked against several known aftermarket prices.)

4. Weights (B.O.M.) used to get material cost

   cold rolled steel @ $.1616 @ 65% yield = $.249/lb
   aluminized steel @ $.2112 @ 65% yield = $.325/lb

5. Difference between manufacturing cost and material cost equals labor plus overhead. Split on 1.0 to 0.4 ratio labor to overhead.

29.7 Standard Steel Exhaust Systems Application

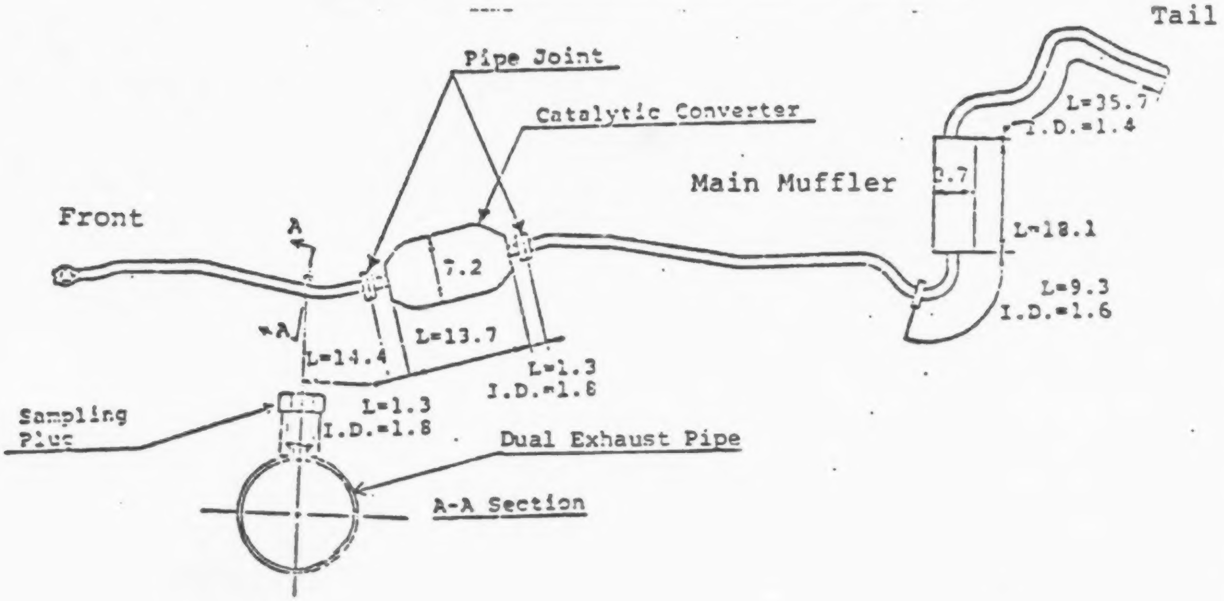
A six-cylinder and 8-cylinder exhaust system was estimated to differentiate the costs for V-exhaust pipe and resonators. A Chrysler-type catalyst was assumed in the configurations.

Other applications are similar.

30.0 **Insulated Exhaust Pipe** (cost per foot of double wall stainless steel exhaust pipe)

The data will be developed for Allegheny Ludlum 409 stainless and aluminized carbon steel. The 409 stainless is currently quoted at $.38 per pound. Quotations are being obtained for aluminized steel tubing.

Double Wall Exhaust Pipe Configuration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Pipe Joint
Catalytic Converter
Main Muffler
Front
A
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L=35.7
I.D.=1.4
8.7
L=18.1
L=9.3
I.D.=1.6
A
L=14.4
L=13.7
L=1.3
I.D.=1.8
L=1.3
I.D.=1.8
Sampling Plug
Dual Exhaust Pipe
A-A Section

30.0 Exhaust System - Double Walled - Insulated Stainless Steel Exhaust Pipe for 6-Cylinder (225 CID) and 8-Cylinder (318 CID)

This analysis considers that the exhaust pipe section from the exhaust manifold to the catalytic converter be constructed of double walled insulated stainless steel pipe. The two major types are for 6-cylinder and 8-cylinder engines. The systems are illustrated in section 29.0.

30.1 Exhaust System - Double Walled - Insulated Stainless Exhaust

CID 225 - 6 Cyl

	Weight	Type Material	Material (+ 35%)	Labor	O.H.	Mfg. Cost
Exh. pipe (double)	15.50	S.S.	$16.32	$ .75	$ .30	$17.37
Exten. pipe	3.00	Aluminum Steel	.98	.18	.07	1.23
Brackets, clamps	.80	Steel	.20	.09	.03	.32
Hardware	.22	Steel	.05	.07	.03	.15
Insulation	.55	Fib. Glass	3.71	.02	.01	3.74
Muffler	9.22	Steel	2.30	.86	.35	3.51
Brakcets, clamps	.32	Steel	.08	.07	.03	.18
Hardware	.09	Steel	.02	.06	.03	.11
Tail pipe	5.00	Aluminum Steel	1.63	.24	.10	1.97
Brackets, clamps	1.63	Steel	.41	.11	.05	.57
Hardware	.07	Steel	.02	.06	.02	.10
Totals	36.40		$25.72	$2.51	$1.02	$29.25

S.S. = .78/lb. + 35%
All items except 1 & 5 from steel
Insulation = woven fiber glass

30.1 Exhaust System - Double Walled, Insulated Stainless Exhaust
CID 318 - 8 Cyl

	Weight	Type Material	Material (+ 35%)	Labor	O.H.	Mfg. Cost
Exh. pipe (double)	27.42	S.S.	$28.87	$1.15	$ .46	$30.48
Exten. pipe	3.00	Aluminum Steel	.98	.18	.07	1.23
Brackets, clamps	.41	Steel	.10	.07	.03	.20
Hardware	.64	Steel	.16	.08	.03	.27
Insulation	.73	Fib. Glass	3.65	.03	.01	3.69
Muffler	10.99	Steel	2.74	1.01	.41	4.16
Brakcets, clamps	.66	Steel	.16	.09	.03	.28
Hardware	.24	Steel	06	.06	.03	.15
Resonator	5.30	Steel	1.32	.54	.22	2.08
Tail pipe	5.00	Aluminum Steel	1.63	.24	.10	1.97
Brackets, clamps	1.88	Steel	.47	.12	.05	.64
Hardware	.03	Steel	.01	.06	.02	.09
Totals	56.30		$40.15	$3.63	$1.46	$45.24

S.S. = .78/lb. + 35%
All items except 1 & 5 taken from steel
Insulation = woven fiber glass

30.2 Exhaust System - Double Walled - Insulated Stainless Steel Exhaust Pipe

Tooling Costs

Amortization Per Piece

Part	Economic Volume	1 Year Recurring Tooling	3 Year Nonrecurring Tooling	12 Year Machinery and Equipment	12 Year Launching Costs	40 Year Land and Building	Amortization Per Piece
6 Cylinder DWSS Exh. pipe	1,000,000	.0750 75,000	.0750 225,000	.0150 180,000	.0015 18,000	-	.1665
Insulation	5,000,000	.0100 50,000	.0100 150,000	.0020 120,000	.0002 12,000		.0222
8 Cylinder DWSS Exh. pipe	1,000,000	.0750 75,000	.0750 225,000	.0150 180,000	.0015 18,000	-	.1665
Insulation	5,000,000	.0100 50,000	.0100 150,000	.0020 120,000	.0002 12,000	-	.0222

R&D Estimate - $300,000/year for 1,000,000 car/year or .30 per vehicle.

30.3 Exhaust System - Double Walled Insulated Stainless Steel Exhaust Pipe

Total Manufacturing Costs

Part	Material	Labor	Plant Overhead	Plant Mfg. Costs	Tooling Exp.	Tooling Inv.	Corp. Alloc. .20MC	Corp. Profit .20MC	Vendor Mfg. Costs
6 Cylinder Exhaust Pipe	16.3200	.7500	.3000	17.3700	.1500	.0165	3.4740	3.4740	24.4845
Insulation	3.7100	.0200	.0080	3.7380	.0200	.0022	.7476	.7476	5.2554
Total									29.7399
8 Cylinder Exhaust Pipe	28.8700	1.1500	.4600	30.4800	.1500	.0165	6.0960	6.0960	42.8385
Insulation	3.6500	.0300	.0100	3.6900	.0200	.0022	.7380	.7380	5.1882
Total									48.0267

30.4 Exhaust System - Double Walled Insulated Stainless Steel Exhaust Pipe

Retail Price Equivalent at the Vehicle Level

Part	Plant Vendor Costs	R&D	Tools and Equip.	Corp. Alloc. .20VC	Corp. Profit .20VC	Dealer Markup .40VC	Vehicle Retail Price Equivalent
6 Cylinder Insul. Exh. Pipe	29.7399	.3000	-	5.9480	5.9480	11.8960	53.8318
8 Cylinder Insul. Exh. Pipe	48.0267	.3000	-	9.6053	9.6053	19.2107	86.7481

No added costs at the vehicle assembly level, nor at the engine assembly level.

30.5 Exhaust System - Double Walled - Insulated Stainless Steel Exhaust Pipe Cost Comparison to Aftermarket Selling Prices

No aftermarket selling price was available for this design so we assumed the normal (4X) markup over vendor costs.

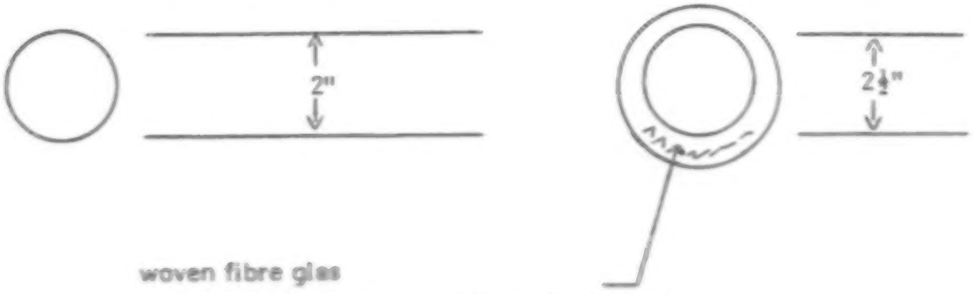
Exhaust Pipe	Vendor Costs	Estimated Aft. S. P. (4xV.C.)
6 Cylinder	29.7399	118.9596
8 Cylinder	48.0267	192.1068

30.6 Exhaust System - Double Walled Insulated Stainless Steel Exhaust Pipe

Cost Methodology

Refer to 29.6 for details of the cost methodology. Chrysler data were used for weight and configuration data.

Design concept

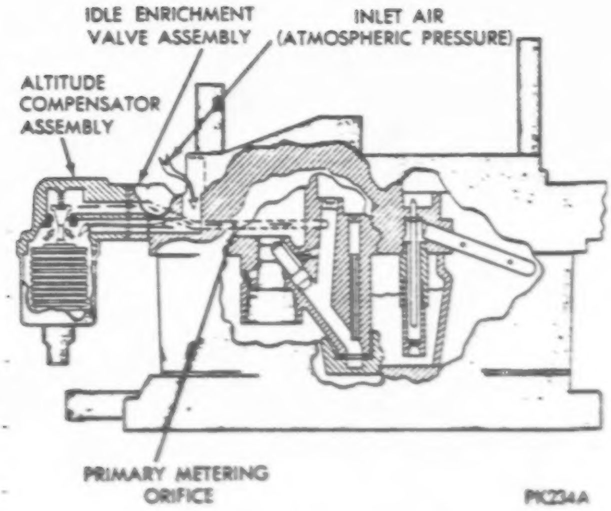


30.7 Exhaust System - Double Walled Insulated Stainless Steel Pipe for 6 and 8 cylinder engines

Application by Engine

The data were developed for a 6 cylinder 225 CID engine and an 8 cylinder 318 CID engine. Other engine applications will be similar or proportional.

31.0 CARBURETOR MODIFICATIONS FOR ALTITUDE COMPENSATION


IDLE ENRICHMENT VALVE ASSEMBLY
INLET AIR (ATMOSPHERIC PRESSURE)
ALTITUDE COMPENSATOR ASSEMBLY
PRIMARY METERING ORIFICE
PIC234A

Altitude Compensator System

31.0 Carburetor Modifications for Altitude Compensation

In order to maintain the appropriate fuel/air mixture while under the influence of a thin atmosphere, a main system altitude compensation circuit has been incorporated into the design of the Thermo-Quad carburetor for most California models. The modification affects the primary metering systems as follows:

A small cylindrical bellows chamber mounted on the front of carburetor, is vented directly to atmosphere. Atmospheric pressure changes expands or contracts the bellows. A small brass tapered-seat valve regulates air flow when it is raised off its seat by the expanding bellows. A small spring is positioned on top of the tapered valve between the valve and housing. The function of the spring is to help maintain the valve in the closed position when the system is exposed to a marginal pressure head (one which is neither sufficient to hold the valve at the proper altitude), and to mechanical vibrations which would tend to unseat the valve during the above condition. When the appropriate environment is encountered and extra air is required, (as determined by the bellows) it is supplied to the primary main air bleeds through a calibrated orifice that meters the proper amount of air to the air bleed.

The system operates as follows: Some time during engine operation a thin atmosphere is encountered, producing an increasingly rich fuel/air mixture. At a mechanically pre-determined point the bellows begin to expand allowing additional air to enter the main air bleeds. The auxiliary air, coupled with the present air source, provides the system with the proper amount of air necessary to maintain the correct fuel/air mixture. The system supplies varying amounts of additional air depending upon different altitudes. When sufficient atmospheric pressure is again restored, the valve closes and the system returns to its normal mode of operation.

31.1 Carburetor Modificaitons for Altitude Compensation

Manufacturing Costs Bill of Material

Part	Material	Weight	Material Costs	Labor Costs	Labor Overhead	Manufacturing Costs	Reference
Altitude Comp. Asm.		.400	-	.1250	.0500	.1750	Chrysler
Carburetor Mod		.100	.0600	.2500	.1000	.4100	
Aneroid	Copper	.120	.0960	.2500	.1000	.4460	
Valve	Steel	.050	.0100	.1250	.0500	.1850	
Cup	Steel	.050	.0100	.0625	.0250	.0975	
Valve Hsg.	Alum	.150	.0900	.3500	.1400	.5800	
Hardware		.030	.0060	.0010	.0004	.0074	
Total						1.9009	

31.2 Carburetor Modifications for Altitude Compensation
Tooling Costs Amortization Per Piece

Part	Economic Volume	1 Year Recurring Tooling	3 Year Nonrecurring Tooling	12 Year Machinery and Equipment	12 Year Launching Costs	40 Year Land and Building	Amortization Per Piece
Alt. Comp. Asm.	1,000,000	.0100 10,000	.0100 30,000	.0020 24,000	.0002 24,000	-	.0222
Carburetor Mod	1,000,000	.0200 20,000	.0200 60,000	.0200 240,000	.0020 24,000	-	.0620
Aneroid	1,000,000	.0300 30,000	.0300 90,000	.0100 120,000	.0010 12,000	-	.0710
Valve	1,000,000	.0100 10,000	.0100 30,000	.0100 120,000	.0010 12,000	-	.0310
Cup	1,000,000	.0100 10,000	.0100 30,000	.0100 120,000	.0010 12,000	-	.0310
Valve Hsg.	1,000,000	.0300 30,000	.0300 90,000	.0200 240,000	.0020 24,000	-	.0820
Hardware	10,000,000	.0010 10,000	.0010 30,000	.0010 120,000	.0001 12,000	-	.0031
Total							.3023

Research & Development - $250,00 per year for 3 years for 1,000,000 units per year - .25 per carburetor.

31.3 Carburetor Modifications for Altitude Compensation

Total Manufacturing Costs

Part	Material	Labor	Plant Overhead	Mfg. Costs	Tooling Exp.	Tooling Inv.	Corp. Alloc. .20MC*	Corp. Profit .20MC*	Vendor Mfg. Costs
Alt. Comp. Asm.	-	.1250	.0500	.1750	.0200	.0022	.0350	.0350	.2672
Carburetor Mod	.0600	.2500	.1000	.4100	.0400	.0220	.0820	.0820	.6360
Aneroid	.0960	.2500	.1000	.4460	.0600	.0110	.0892	.0892	.6954
Valve	.0100	.1250	.0500	.1850	.0200	.0110	.0370	.0370	.2900
Cup	.0100	.0625	.0250	.0975	.0200	.0110	.0195	.0195	.1675
Valve Hsg.	.0900	.3500	.1400	.5800	.0600	.0220	.1160	.1160	.8940
Hardware	.0060	.0010	.0004	.0074	.0020	.0011	.0015	.0015	.0135
Total									2.9636

31.4 Carburetor Modification for Altitude Compensation Retail Price Equivalent at the Vehicle Level

Part	Plant Vendor Costs	R&D	Tools and Equip.	Corp. Alloc. .20VC*	Corp. Profit .20VC*	Dealer Markup .40VC*	Vehicle Retail Price Equivalent
Alt. Comp.Asm.	2.9636	.2500	-	.5927	.5927	1.1854	5.5844

31.5 Carburetor Modification for Altitude Compenstion Cost Comparison to Aftermarket Selling Prices

The only data obtainable for the delta increase in carburetor aftermarket selling prices is to compare the California 1977 system with the 49 state carburetor system.

The 2 barrel carburetor prices show a delta of about $20 or about $5.00 if the 1/4 discount is used. The manufacturing/vendor estimate is $2.9636 and the RPE is $5.5844. Since we do not know what the delta price includes this comparison is not conclusive.

31.6 Carburetor Modification for Altitude Compensation Cost Methodology

Using the Chrysler sketch the unit weight of the components was estimated. The materials are also estimated. The costs are based on an ecomony of scale of 1,000,000 units per year.

31.7 Carburetor Modification for Altitude Compensation Applications

It can be assumed that the altitude compensation system will be similar for 1, 2, and 4 barrel carburetors. The costs per system might be slightly less but not significant for this study.

32.0 Carburetor Modifications for Feedback Control

The pictorial schematic in Figure 2 shows the system elements of the basic system. The 0_2 sensor, located in the exhaust stream between the engine and the catalyst, produces a voltage of about 800 millivolts in the absence of oxygen in the exhaust. This voltage decreases to zero as the oxygen in the exhaust stream increases from 0 to $1\frac{1}{2}$%.

The voltage signal from the sensor is the prime control input to the electronic control unit which provides a square wave output signal of constant frequency, but of variable band width depending on the 0_2 sensor voltage. The ECU is designed so that at low values of oxygen in the exhaust (highest level of sensor voltage output), the output signal band width is the greatest. Conversely, as the oxygen concentration increases in the exhaust and the sensor voltage decreases, the band width decreases.

This variable width output signal operates the vacuum control valve, which serves to modulate the vacuum that is applied to the carburetor from the vacuum storage canister. Because the "on time" of the valve is a function of 0_2 sensor signal, the modulated vacuum resulting from variable "on time" is also a function of 0_2.

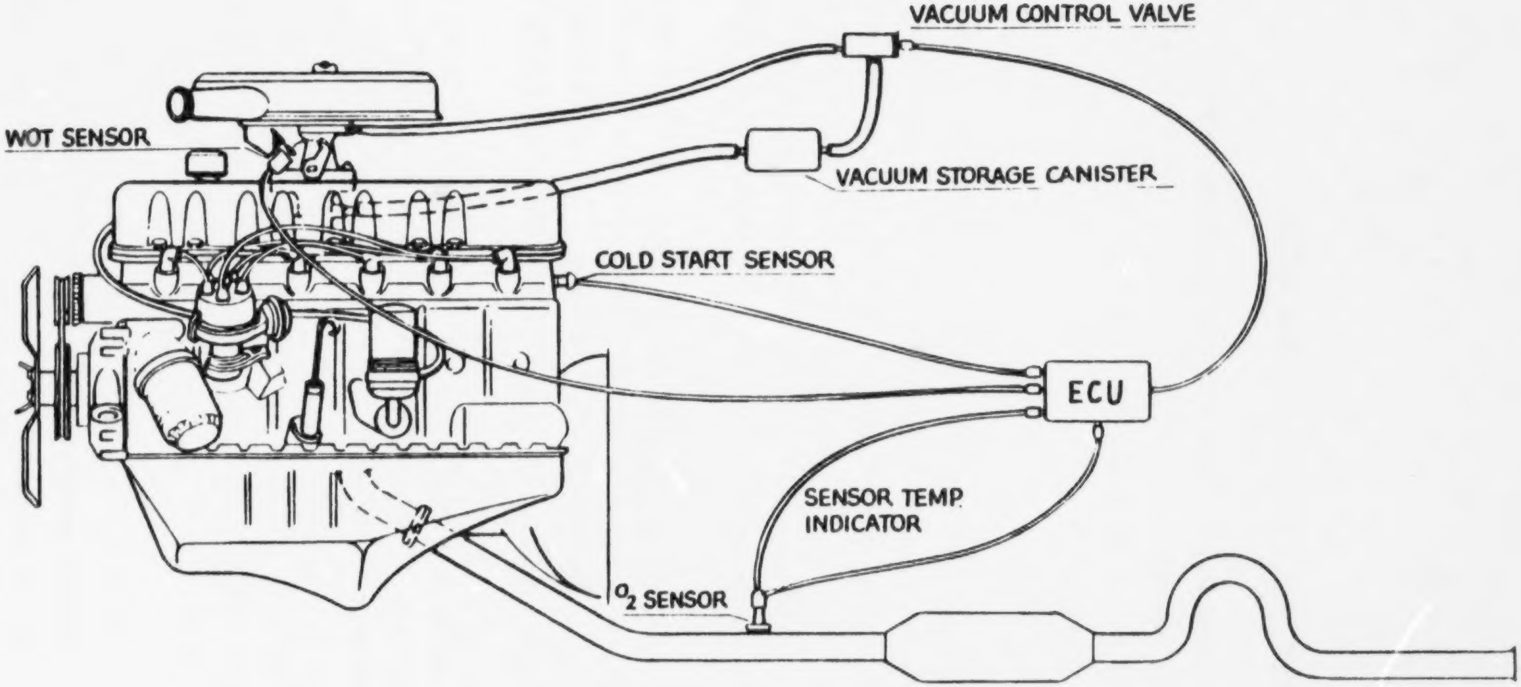
The sensor shows the two systems in the carburetor that are controlled by the modulated vacuum. The idle system is controlled by providing a variable air bleed parallel with the normal air bleed to control idle metering forces.

Control of the main system is accomplished by varying the fuel orifice in parallel with the main metering jet. This construction is a refinement of today's power enrichment system.

In operation, when a high vacuum is applied to the carburetor, it will tend to meter lean. This is accomplished when the solenoid has a high percentage of "on" time. Conversely, when the solenoid is off or operating at a low "on" time level, the control vacuum is low and the carburetor metering will enrichen.

FIGURE 2

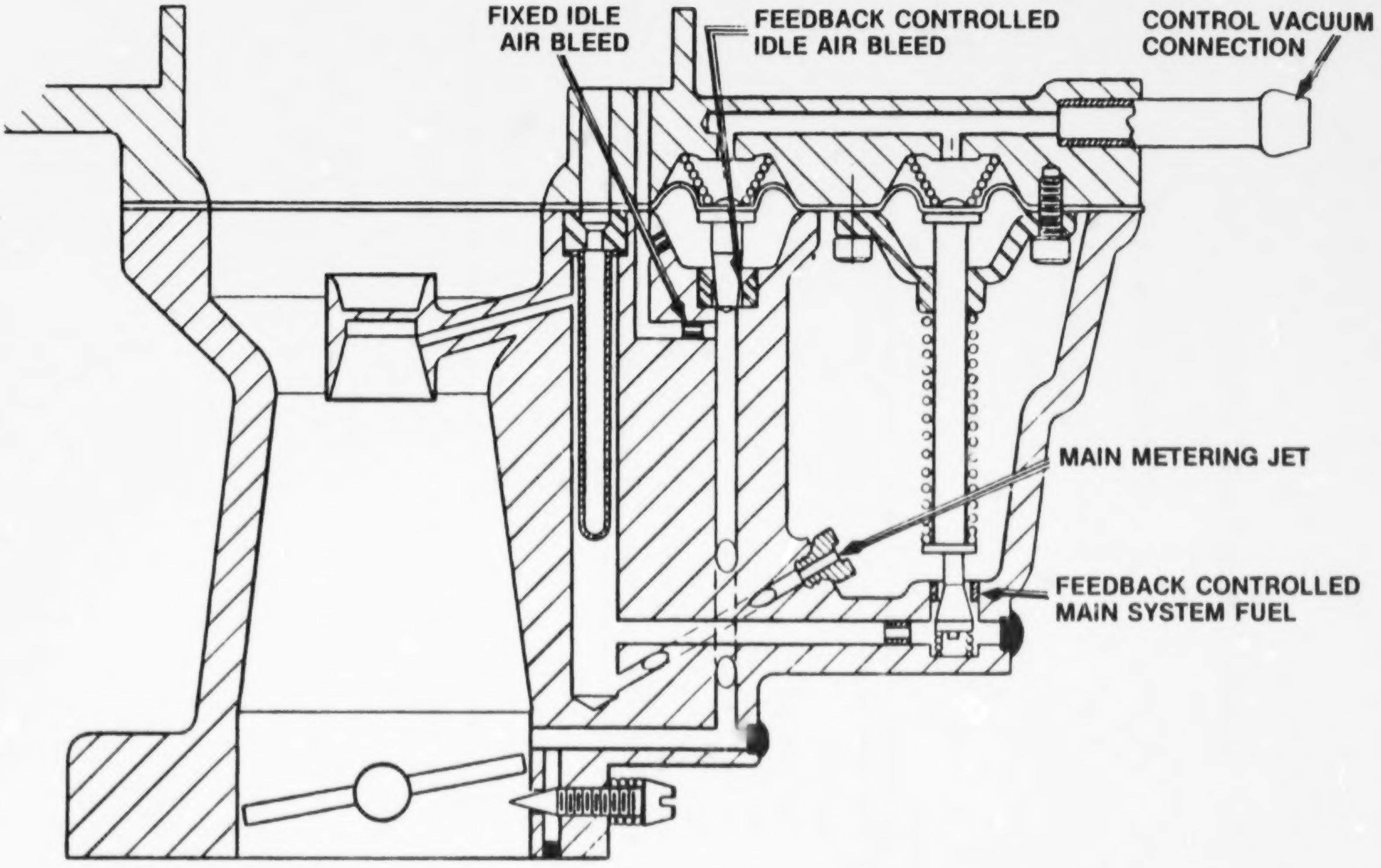
HOLLEY FEEDBACK CARBURETOR ENGINE SYSTEM


VACUUM CONTROL VALVE
WOT SENSOR
VACUUM STORAGE CANISTER
COLD START SENSOR
ECU
SENSOR TEMP. INDICATOR
O_2 SENSOR

PATENT PENDING 1976 HOLLEY CARBURETOR DIVISION

FIGURE 3

FEEDBACK CARBURETOR SCHEMATIC DRAWING


FIXED IDLE AIR BLEED
FEEDBACK CONTROLLED IDLE AIR BLEED
CONTROL VACUUM CONNECTION
MAIN METERING JET
FEEDBACK CONTROLLED MAIN SYSTEM FUEL

32.1 Carburetor Modifications for Feedback Control Unit

MANUFACTURING COSTS

Bill of Material

Part	Mat.	Weight	Mat. Costs	Labor Costs	Overhead Labor Costs	Mfg. Plant Costs	Reference
Mod Carb Assy	--	--	.1000	.5000	.2000	.8000	
Mod Carb	Alum	[illegible]	.6000	.5500	.2200	1.3700	
Fixed Idle Bleed	PM	[illegible]	.0300	.0625	.0250	.1175	Holley
Idle Feedback Valve	PM Steel	.100	.0600	.1250	.0500	.2350	Sketches
FB Fuel Main Valve	PM Steel	.100	.0600	.1250	.0500	.2350	
Contl Vac Conn	Steel	.100	.0200	.0625	.0250	.1075	
			.8700	1.4250	.5700	2.8650	

Note: The vacuum control valve and the vacuum storage cannister are an integral part of this system, but not included in the estimate.

32.2 Carburetor Modifications for Feedback Control Unit

TOOLING COSTS

Amortization per Piece

Part	Economic Volume Per Year	1-Year Recurring Tooling	3-Year Non Recurring Tooling	12-Year Machinery Equipment	12-Year Launching Costs	40-Year Land & Buildings	Amortization Per Piece
Mod Carb Assy	1,000,000	.0500 50,000	.0500 150,000	.0200 240,000	.0020 24,000	--	.1220
Mod Carb	1,000,000	.0500 50,000	.0500 150,000	.0500 600,000	.0050 60,000	--	.1550
Fix Idle Bleed	1,000,000	.0050 5000	.0050 15,000	.0010 12,000	.0001 1200	--	.0111
Idle FB Valve	1,000,000	.0100 10,000	.0100 30,000	.0100 120,000	.0010 12,000	--	.0310
FB Main Valve	1,000,000	.0100 10,000	.0100 30,000	.0100 120,000	.0010 12,000	--	.0310
Contl Vac Conn	1,000,000	.0050 5000	.0050 15,000	.0010 12,000	.0001 12,000	--	
Total		.1300	.1300	.0920	.0092		.3612

R&D - 300,000/year for 3 years for 1,000,000 units/per = $.30/unit

32.3 Carburetor Modifications for Feedback Control Unit

TOTAL MANUFACTURING COSTS

Part	Mat	Labor	Plant Over-Head	Plant Mfg Costs (MC)	Tooling Exp.	Tooling Inv.	.20/MC Corp. Costs	.20/MC Corp. Profit	Mfg/ Vend Costs
F.B. Carburetor	.8700	1.4250	.5700	2.8650	.2600	.1012	.5730	.5730	4.3722

32.4 Carburetor Modifications for Feedback Control Unit

RETAIL PRICE EQUIVALENT AT THE VEHICLE LEVEL

Part	Vendor Costs (VC)	R&D	Tools and Equip	Corp Allocation .20 VC	Corp Profit .20 VC	Dealer Markup .40 VC	RPE Vehicle Level
FB Carburetor	4.3722	.3000	--	.8744	.8744	1.7489	8.1700

32.5 Carburetor Modification for Feedback Control Unit

COST COMPARISON TO AFTERMARKET SELLING PRICES

No aftermarket selling prices are available for a feedback carburetor.

An estimated aftermarket delta might be: 4 x (VC Costs) = 4 x (VC Costs) = 4 x 4.37 = $17.49.

32.6 Carburetor Modification for Feedback Control Unit

COST METHODOLOGY

Since we are dealing with a delta change for the carburetor modifications to provide feedback capabilities, all the costs are based on assumptions.

The weight and cost data are estimates based on judgments using the Chrysler sketches.

32.7 Carburetor Modification for Feedback Control Unit

APPLICATIONS

The feedback carburetor is associated with the 3-way catalysts systems. The applications to various engines is similar to the design presented by Holley.

33.0 Standard Carburetor

The standard carburetor is a complex system of components that provides appropriate mixtures of air and fuel to the intake manifold throughout the various driving cycles of the vehicle.

One of these carburetors is the Holley Model 1945. This carburetor is a single venturi concentric downdraft carburetor equipped on 225 CID 6-cylinder engines. It consists of the following subsystems:

1. Fuel inlet system
2. Idle system
3. Main Metering system
4. Power enrichment system
5. Accelerating pump system
6. Automatic Choke Vacuum Kick system

The dual barrel carburetors such as Carters BBD and the Holley 2245 include an added subsystem called the idle enrichment system. This carburetor is used on 318-V8 CID engines.

The Carter TQ carburetor is a 4-barrel carburetor designed for 360, 400, and 440 CID V8 engines. The subsystems include both low and high speed performance circuits. This carburetor is also designed to incorporate an altitude compensation system. This system will be treated separately in another section of this report.

The basic data for 1975 vehicles are:

Carburetor Part No.	List Price $	Weight lbs.	Vehicle
3830576	$112.00	5.550	Valiant 225
3830565	79.35	4.510	Satellite 318
3830563	87.24	6.710	Fury 360

Choke Part No.	List Price $	Weight lbs.	Vehicle
3830549	$ 10.22	.250	Valiant
3830512	7.25	.190	Satellite
3751476	12.55	.250	Fury (et al)

Source: Chrysler Data

The costs will be gross estimates since a complete analysis involves estimating between 100 to 230 components.

These carburetors provide an interface subsystem for EGR systems.

33.1 Standard Carburetor

Manufacturing Costs

Bill of Material

	Material	Weight	Material Costs	Labor Costs	Labor Overhead	Manufacturing Costs	Reference
Carburetor 1		4.510					
Primary Parts	Alum.	4.014	2.4084	3.5000	1.4000	7.3084	
Secondary Parts		.496	.0992	.4000	.1600	.6592	
Total			2.5076	3.9000	1.5600	7.9676	
Carburetor 2		5.500					
Primary Parts	Alum.	4.895	2.9370	4.2000	1.6800	8.8170	
Secondary Parts		.605	.1210	.5000	.2000	.8210	
Total			3.0580	4.7000	1.8800	9.6380	
Carburetor 4		6.710					
Primary Parts	Alum.	5.472	3.2822	5.2500	2.1000	10.6322	
Intermediate Pts	Phenolic	.500	.3500	.3000	.1200	.7700	
Secondary Parts	Steel	.738	.1476	.7000	.2800	1.1276	
Total			3.7798	6.2500	2.5000	12.5298	
Choices	Steel	.250	.050	.3500	.1400	.5400	

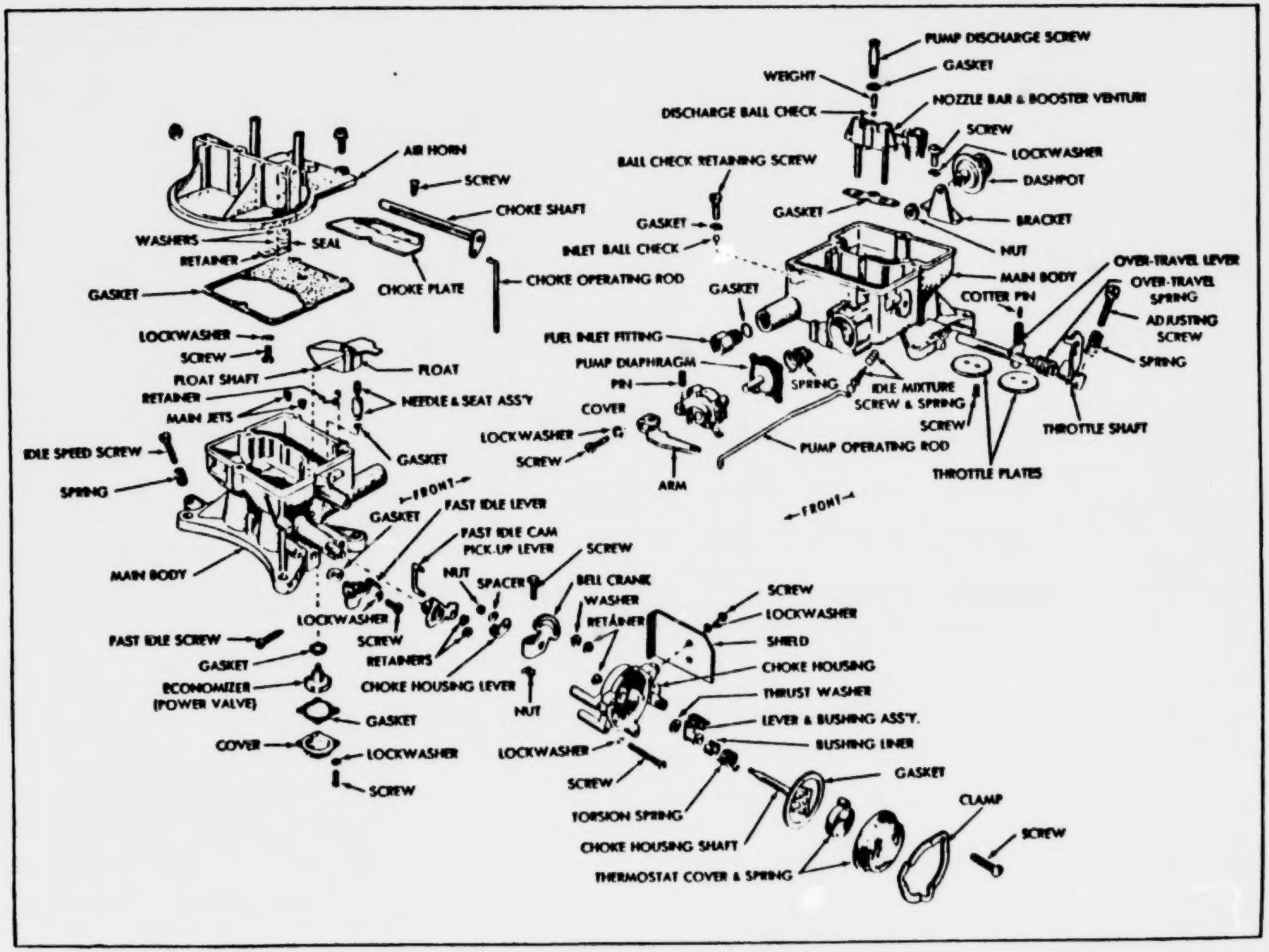
33.2 Standard Carburetor
Tooling Costs
Amortization Per Piece

Part	Economic Volume	1 Year Recurring Tooling	3 Year Nonrecurring Tooling	12 Year Machinery and Equipment	12 Year Launching Costs	40 Year Land and Building	Amortization per Piece
		.1000	.2000	1.0000	.1000		
Carburetor 1	1,000,000	100,000	600,000	12,000,000	1,200,000		1.4000
		.1000	.1333	1.0000	.0625		
Carburetor 2	2,000,000	200,000	800,000	24,000,000	1,500,000		1.2955
		.1500	.2500	1.5000	.0833		
Carburetor 4	2,000,000	300,000	1,500,000	36,000,000	2,000,000		1.9833

33.3 Standard Carburetor

Total Manufacturing Costs

	Material Costs	Labor Costs	Plant Overhead	Plant Mfg. Costs	Tooling		Corp. Alloc. .20 MC	Corp. Profit .20MC	Mfg. Vendor Costs
					Exp.	Inv.			
Carburetor 1	2.5076	3.9000	1.5600	7.9676	.3000	1.100	1.5935	1.5935	12.5546
Carburetor 2	3.0580	4.7000	1.8800	9.6380	.2333	1.0625	1.9276	1.9276	14.7890
Carburetor 4	3.7798	6.2500	2.5000	12.5298	.4000	1.5833	2.5060	2.5060	19.5250


PUMP DISCHARGE SCREW
GASKET
WEIGHT
NOZZLE BAR & BOOSTER VENTURI
DISCHARGE BALL CHECK
SCREW
LOCKWASHER
DASHPOT
BALL CHECK RETAINING SCREW
GASKET
BRACKET
GASKET
NUT
INLET BALL CHECK
OVER-TRAVEL LEVER
MAIN BODY
OVER-TRAVEL SPRING
GASKET
COTTER PIN
ADJUSTING SCREW
FUEL INLET FITTING
SPRING
PUMP DIAPHRAGM
SPRING
IDLE MIXTURE SCREW & SPRING
PIN
COVER
SCREW
THROTTLE SHAFT
LOCKWASHER
SCREW
PUMP OPERATING ROD
ARM
THROTTLE PLATES
FRONT
AIR HORN
SCREW
CHOKE SHAFT
WASHERS
SEAL
RETAINER
CHOKE PLATE
CHOKE OPERATING ROD
GASKET
LOCKWASHER
SCREW
FLOAT SHAFT
FLOAT
RETAINER
NEEDLE & SEAT ASS'Y
MAIN JETS
IDLE SPEED SCREW
GASKET
SPRING
FRONT
GASKET
FAST IDLE LEVER
FAST IDLE CAM PICK-UP LEVER
SCREW
MAIN BODY
NUT
SPACER
BELL CRANK
WASHER
RETAINER
SCREW
LOCKWASHER
SHIELD
LOCKWASHER
SCREW
FAST IDLE SCREW
RETAINERS
GASKET
CHOKE HOUSING LEVER
CHOKE HOUSING
ECONOMIZER (POWER VALVE)
NUT
THRUST WASHER
GASKET
LEVER & BUSHING ASS'Y.
COVER
LOCKWASHER
LOCKWASHER
BUSHING LINER
SCREW
SCREW
GASKET
CLAMP
TORSION SPRING
SCREW
CHOKE HOUSING SHAFT
THERMOSTAT COVER & SPRING

Ford two-barrel carburetor

33.4 Standard Carburetor

Retail Price Equivalent at the Vehicle Level

Part	Vendor Costs	R&D	Tools and Equip.	Alloc. .20VC*	Profit .20VC*	Markup .40VC*	Price Equivalent
Carb 1	12.5546	-	-	2.5109	2.5109	5.0218	22.5983
Carb 2	14.7890	-	-	2.9578	2.9578	5.9156	26.6202
Carb 4	19.5250	-	-	3.9050	3.9050	7.8100	35.1450

33.5 Standard Carburetor

Cost Comparison to Aftermarket Selling Prices

Using the aftermarket prices and the discount data we can make the following comparison to the manufacturing cost estimates.

				Estimates	
	List Price	¼ Discount		Vendor Cost	RPE
		1/4	1/5		
Carb 1	79.35	19.84	15.87	12.55	22.60
Carb 2	87.24	21.81	17.65	14.79	26.62
Carb 4	112.00	28.00	22.40	19.52	35.14

33.6 Standard Carburetor

Cost Methodology

The weight and selling price data were obtained from Chrysler engineering data and sales catalogs.

The costs are estimates based on judgment. The estimates are not supported by detail costs of each component. Therefore, these estimates are gross estimates using weight data and material type selections.

33.7 Standard Carburetor

Applications

As stated previously, the 1, 2, & 4 barrel carburetors are usually associated with 225 CID, 318 CID, 360 CID and over engines. In recent years, domr 4 barrel applications have been replaced by 2 barrel carburetors.

The altitude compensation and electronic feedback subsystems have been treated separately.

34.0 Electronic Control Unit (with sensor inputs for controlling modulated AIR, modulated EGR, modulated A/F, and modulated spark advance)

34.1 Electronic Control Unit

MANUFACTURING COSTS

Bill of Material

Part	Mat.	Weight	Mat Costs Purch.	Labor	Overhead	Mfg. Costs	
ECU Assy				15.50	6.200	21.70	Test
Power Transistor	--	--	2.00			2.00	
Rectifier	--	--	1.00			1.00	
T^2L 14 Pin DIP IC	--	--	2.00			2.00	
Low Power Trans	--	--	.80			.80	
Signal Trans	--	--	2.00			2.00	
Carbon Resist	--	--	.80			.80	
Capacitor	--	--	2.00			2.00	
Ceramic Resistor	--	--	.50			.50	
PC Boards	--	--	2.00			2.00	
Conn and Pins	--	--	1.00			1.00	
Press Transducer	--	--	1.00			1.00	
Outer Shell	--	--	1.00			1.00	
Other	--	--	1.90			1.90	
Totals			18.00	15.50	6.20	39.70	

Based on current technology--not on LSI technology--LSI technology would probably be 30 to 50% less.

34.2 Electronic Control Unit

TOOLING COSTS

Amortization per Piece

Part	Economic Volume Per Year	1-Year Recurring Tooling	3-Year Non Recurring Tooling	12-Year Machinery Equipment	12-Year Launching Costs	40-Year Land & Buildings	Amortization Per Piece	
		.0100	.0100	.0625	.0062			Lean
ECU Unit	2,000,000	20,000	60,000	1,500,000	150,000	--	.0887	Burn

34.3 Electronic Control Unit

TOTAL MANUFACTURING COSTS

	Mat. Costs	Labor Costs	Over-Head	Mfg. (MC) Costs	Tooling	Corp. .20MC Alloc	Corp. .20MC Profit	Plar Ven Cos
ECU	18.00	15.50	6.20	39.70	.0887	7.940	7.940	55.

R & D - 2,000,000/year for 3 years for 2,000,000/year = 1.0000 R&D per vehicle.

34.4 Electronic Control Unit

RETAIL PRICE EQUIVALENT AT THE VEHICLE LEVEL

	Vendor/ Mfg. Costs (VC)	R&D	Tools and Equip	Corp Allocation .20 VC	Corp Profit .20 VC	Dealer Markup .40 VC	Vehicle Retail Price Equiv.
ECU Unit	55.67	1.00	--	11.13	11.13	22.27	101.21

This estimate is based on today's technology. Using learning curve data from the electronics industry, we can assume a 28% cost improvement for every doubled quantity. (Includes LSI technology).

Volume	RPE
2,000,000	101.21
4,000,000	72.87
8,000,000	52.47
16,000,000	37.78
32,000,000	27.20

34.5 Electronic Control Unit

AFTERMARKET ANALYSIS

The ECU units are being sold for $60 to $90 in the aftermarket with the VW unit at $222. The discount formula of ¼ computes the following:

			1/4 Discount	
AFT	SP	$60.00	15.00	(modulator)
AFT	SP	90.00	25.00	(Ford modulator)
AFT	SP	222.00	55.50	(VW - ECU)

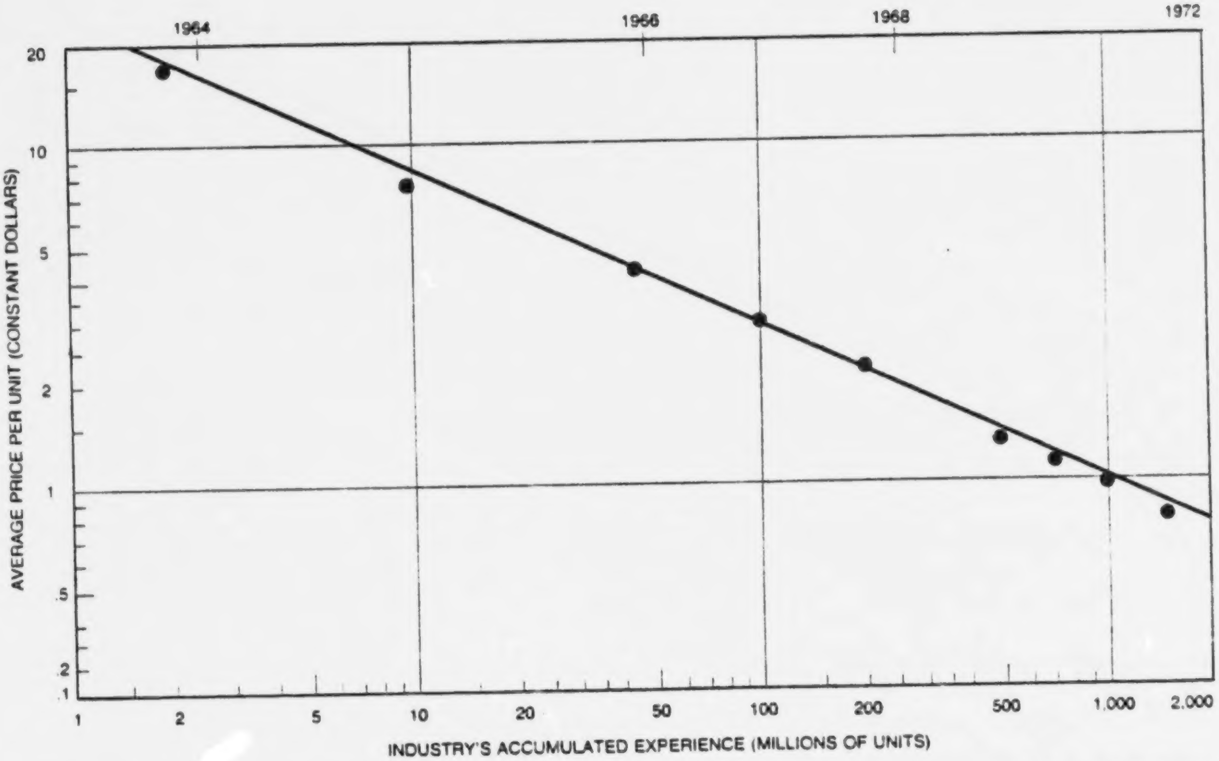
34.6 Electronic Control Unit

COST METHODOLOGY

The material cost data are estimates from a plant visitation. The tooling and process data were obtained from the same source.

34.6 Electronic Control Unit

COST METHODOLOGY



PRICES OF INTEGRATED CIRCUITS have conformed to an experience curve common to many industries, declining about 28 percent with each doubling of the industry's cumulative experience (as measured by the number of units produced). It is the particularly rapid growth of the microelectronics industry that has made the rate of decline in prices appear to be higher than the rate in other industries.

Fig. 1 Operational Flow Diagram

Operation		Remarks
Incoming Inspection	(10)	100% temperature test of all semiconductors
	Board 1 Board 2	
Automatic Component insertion	(15)	about 50 parts per board, 1 part per station
Individual semi-automatic insertion of power, semiconductor & IC's	(7)	
Flow Solder	(2)	
1st unit test (parts test) and print out for trouble shoot	(2)	
2nd unit test (functional)	(2)	
Laser trim of ceramic resistor (trim to functional performance & trouble shoot)	(4)	
Automatic potting	(4)	Silicone
Post pat test	(2)	85° C
ECU Assembly	(6)	
Test	(2)	
Burn in	(2)	85°C 8 hrs
Test	(2)	Total production operators per shift (63)
Rack & Ship	(2)	+ undefined of 12 = 75 total

Table I

Test Equipment Estimate

Incoming Inspection	6 units at 40K each	$240,000
1st unit test - parts	2 units at 40K	80,000
2nd unit test	2 units plus computer	100,000
Laser resister term	1 unit	75,000
Post potting test	2 units at 25K	50,000
Burn in racks & test monitor	4 at 30,000	120.000
Total unit test	1 at 30,000	30,000
		695,000
	+ undefined	305,000
		1,000,000

Table II

Estimated Production Equipment

Automatic parts insertion	100 @ 1000 each	100,000
Parts insertion transport line	2 @ 20,000	40,000
Automatic Potting line	1 @ 50,000	50,000
Flow Soldex Machine (2 parallel lines in 1 machine)		30,000
Special stepping, assembly stations		100,000
		320,000
	other undefined	180,000
		500,000

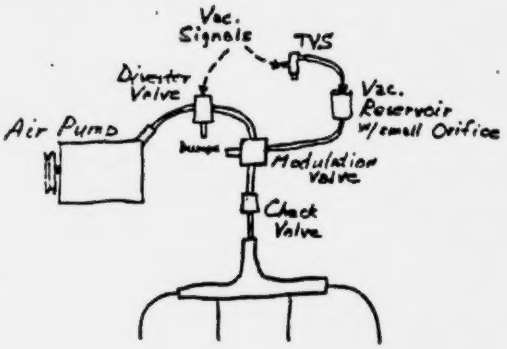
34.7 Electron Control Unit

APPLICATIONS

The variations in costs of ECU units will be dependent on the number of cylinders. The deltas will not be significant at this stage of technology.

35.0 AIR MODULATION SYSTEM WITH VACUUM CONTROL

The air modulation system provides an appropriate volume of secondary air to the exhaust ports (or to a point between the 3-way catalyst and the oxidation catalyst) dependent upon both engine speed and load or, in other words, the volume of engine exhaust. This system attempts to more nearly match this air supply with engine needs for optimum oxidation of HC and CO while minimizing the cooling effect this air has on the exhaust gases. It consists of a diverter type valve that is actuated by a vacuum signal from intake manifold that in turn provides air to the exhaust stream.


Vac. Signals
TVS
Diverter Valve
Vac. Reservoir w/small Orifice
Air Pump
Modulation Valve
Check Valve

Air Modulation System

Same as air injection system except:

- vac. line to TVS
- TVS
- vac. line to Vac. Res.
- Vac. Res. (same as above)
- vac. line from Vac. Res. to Mod. Valve
- Modulation Valve (same as diverter valve except with calibrated spring rate and more durable diaphragm)

35.2 Air Modulation System

Tooling Costs--Amortization Per Part

Part	Economic Volume	1 Year Recurring Tooling	3 Year Nonrecurring Tooling	12 Year Machinery and Equipment	12 Year Launching Costs	40 Year Land and Building	Amortization Per Piece	Reference
Diverter Valve	2,500,000	.0580 145,000	.0580 435,000	.0167 500,000	.0017 50,000	-	.1343	6.2
Converter Hose	2,500,000	.0040 10,000	.0016 12,000	.0026 78,000	.0003 7,800		.0085	Diverter Valve
Vacuum Hose	2,500,000	.0004 1,000	.0002 1,500	.0003 7,800	.0001 3,000		.0010	Tooling Data
		.0200	.0100	.0050	.0005		.0355	"
Air Manifold	2,500,000	50,000	75,000	120,000	12,000			
Total		.0824	.0698	.0247	.0026		.1793	
Vehicle Assem.	500,000	-	-	-	-		-	
Engine Mod.	500,000	-	-	-	-		-	

Research and Development Estimate: $150,000 for 3 years, or $.1000 Per Piece

35.1 Air Modulation System
Bill of Material
Manufacturing Costs

Part	Material	Weight	Material Costs	Labor Costs	Labor Overhead	Manufacturing Costs	Reference
Diverter Valve	Steel	1.230	.3300	.3435	.1374	.8109	Sketch and
Converter Hose	Rubber	.500	.1000	.0312	.0125	.1437	EPA Data
Vacuum Hose	Rubber	.050	.0100	.0031	.0012	.0143	
Air Manifold	Steel	.100	.0200	.0312	.0125	.0637	
Total						1.0326	
Vehicle Assem.			-	.0625	.0250	.0875	
Engine Mod.			-	.0156	.0062	.0218	
Vehicle Total						1.1419	

35.3 Air Modulation System--Total Manufacturing Costs

Part	Material	Labor	Plant Overhead	Plant Mfg. Costs	Tooling Exp.	Tooling Inv.	Corp. Alloc. .20MC*	Corp. Profit .20MC*	Vendor Mfg. Costs
Diverter Valve	.3300	.3435	.1374	.8109	.1160	.0184	.1622	.1622	1.2697
Converter Hose	.1000	.0312	.0125	.1437	.0056	.0029	.0287	.0287	.2097
Vacuum Hose	.0100	.0031	.0012	.0143	.0006	.0004	.0029	.0029	.0210
Air Manifold	.0200	.0321	.0125	.0637	.0300	.0055	.0127	.0127	.1247
Total									1.6251

35.4 Air Modulation System Retail Price Equivalent At The Vehicle Level

Part	Plant Vendor Costs	R&D	Tools and Equip.	Corp. Alloc. .20VC*	Corp. Profit .20VC*	Dealer Markup .40VC*	Vehicle Retail Price Equivalent
Air Mod. System	1.6251	.1000	-	.3250	.3250	.6500	3.0252
Vehicle Assem.	.0875	-	-	.0175	.0175	.0350	.1575
Engine Mod.	.0218	-	-	.0044	.0044	.0087	.0392
Total RPE							3.2219

35.5 AIR MODULATION SYSTEM COST COMPARISON TO AFTERMARKET SELLING PRICES

An assumption was made that the air modulation valve would be similar to a diverter valve. (See E.P.A. sketch)

A diverter valve is priced at		$18.05
1/4 discount	=	4.51
1/5 discount	=	3.61

The RPE estimate is 3.0252 for the valve and the hoses. The manufacturing (vendor) estimate is 1.6251 for the valve and an added .1093 for the engine and assembly costs.

35.6 AIR MODULATION SYSTEM COST METHODOLOGY

The estimates were based on the diverter valve costs developed in the air injection section 6.0.

Other costs of the engine modifications and the assembly are estimates of the incremental changes required for this system.

35.7 AIR MODULATION SYSTEM APPLICATIONS TO VARIOUS ENGINES

No significant engine-to-engine costs are evident.

36.0 Spark Knock Sensor (with prize electric accelerometer or pickup)

The data for these systems are very limited at the time of this report. Detailed bills of material are not available so only a gross estimate is feasible. It is only a judgment cost estimate based on experience.

36.1 Spark Knock Sensor

The manufacturing costs of the knock sensor based on the schematic drawing indicates that a $40 to $60 costs will be a likely costs.

The RPE costs including the accelerometer is estimated to be $60 to $90 per unit.

No aftermarket data are available at this date.

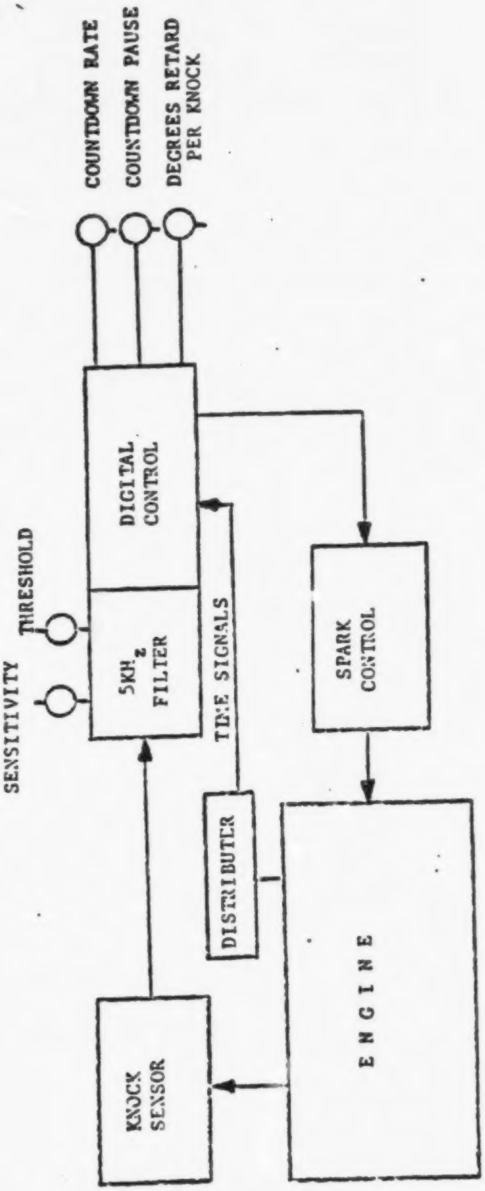
Further work is necessary to develop specific cost data.

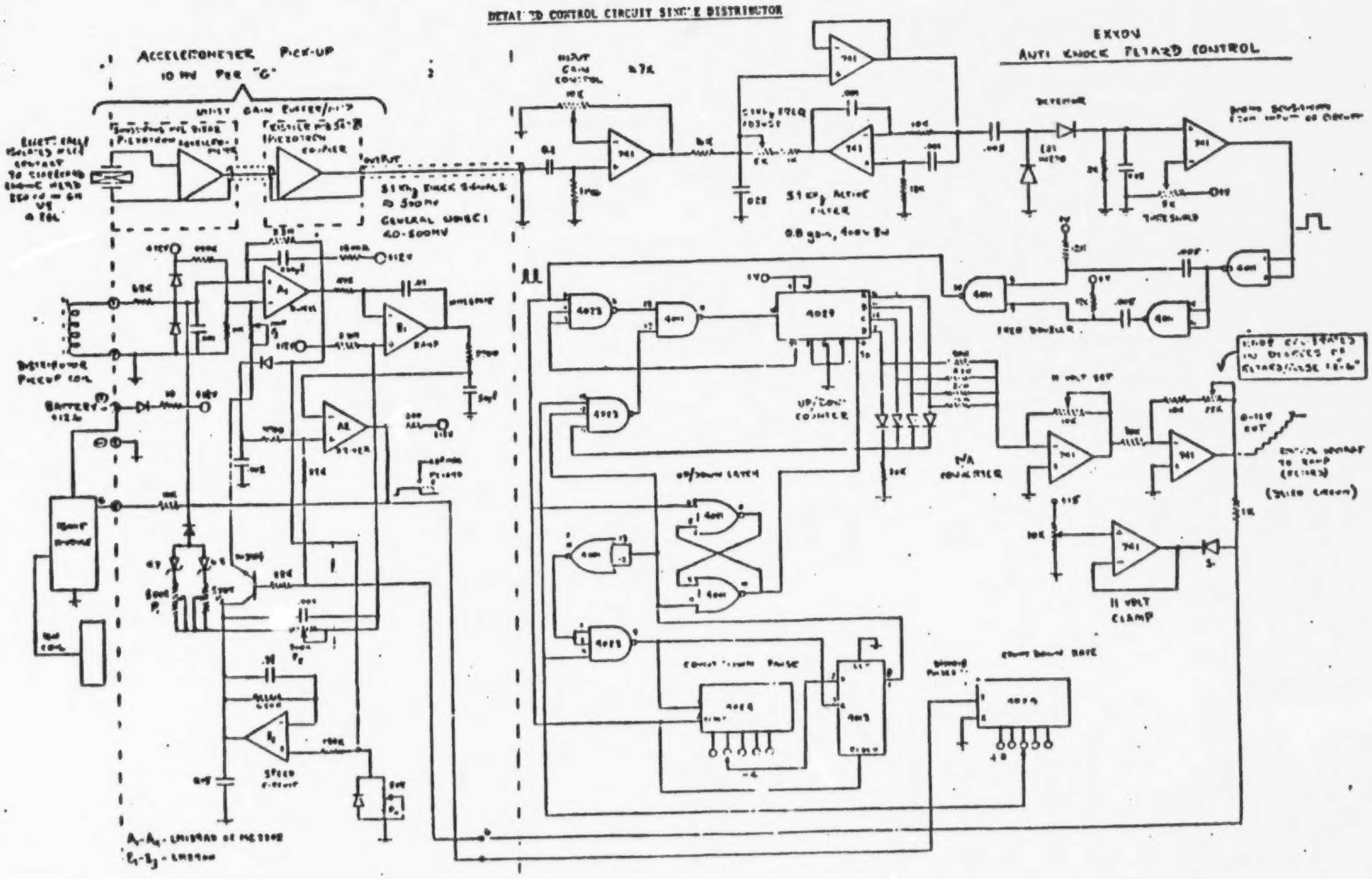
KNOCK SENSOR

(Nonproduction Item)

ATTACHMENT III

KNOCK-SENSOR ACTUATED SPARK CONTROL


COUNTDOWN RATE
COUNTDOWN PAUSE
DEGREES RETARD PER KNOCK
SENSITIVITY
THRESHOLD
5KHz FILTER
DIGITAL CONTROL
TIME SIGNALS
SPARK CONTROL
DISTRIBUTER
ENGINE
KNOCK SENSOR

DETAILED CONTROL CIRCUIT SINGLE DISTRIBUTOR
EXXON
ANTI KNOCK RETARD CONTROL
ACCELEROMETER PICK-UP
10 MV PER "G"
UNITY GAIN BUFFER
OUTPUT
GENERAL NOISE
40-500MV
INPUT GAIN CONTROL
10K
741
STAGE ACTIVE FILTER
0.8 gain, 400 BW
DETECTOR
THRESHOLD
FREQ DOUBLER
4011
4023
4029
UP/DOWN COUNTER
UP/DOWN LATCH
D/A CONVERTER
11 VOLT CLAMP
COUNT DOWN RATE
SPEED CIRCUIT
BATTERY +12V
DISTRIBUTOR PICKUP COIL
RAMP
A₁-A₄ - LM3900 OR MC3301

37.0 Transducers and Sensors

(Types H_2O temperature, inlet air temperature, throttle position, transmission gear, EGR pintol position, crank angle, humidity.)

Some of these sensors are included in the cost analysis of EFI and ECU data.

These data can be pulled from Sections 34.0 and 18.0.

37.1 Transducers and Sensors

37.2 Transducers and Sensors

37.3 Transducers and Sensors

37.4 Transducers and Sensors--Manufacturing Costs and RPE Costs

Using data from the Electronic fuel metering system (18.0), we have:

	5000 K	
Sensor	Mfg./Vendor	RPE
O_2 Sensor	1.75	3.15
Air Temperature	.93	1.67
H_2O	.93	1.67
Pressure Regulator	1.91	3.43
Speed Sensor	.56	1.00
Throttle Switch	1.71	3.07

These data include tooling amortization.

37.5 Transducers and Sensors

The aftermarket cost comparison data are limited to foreign car data and are not useful for analysis.

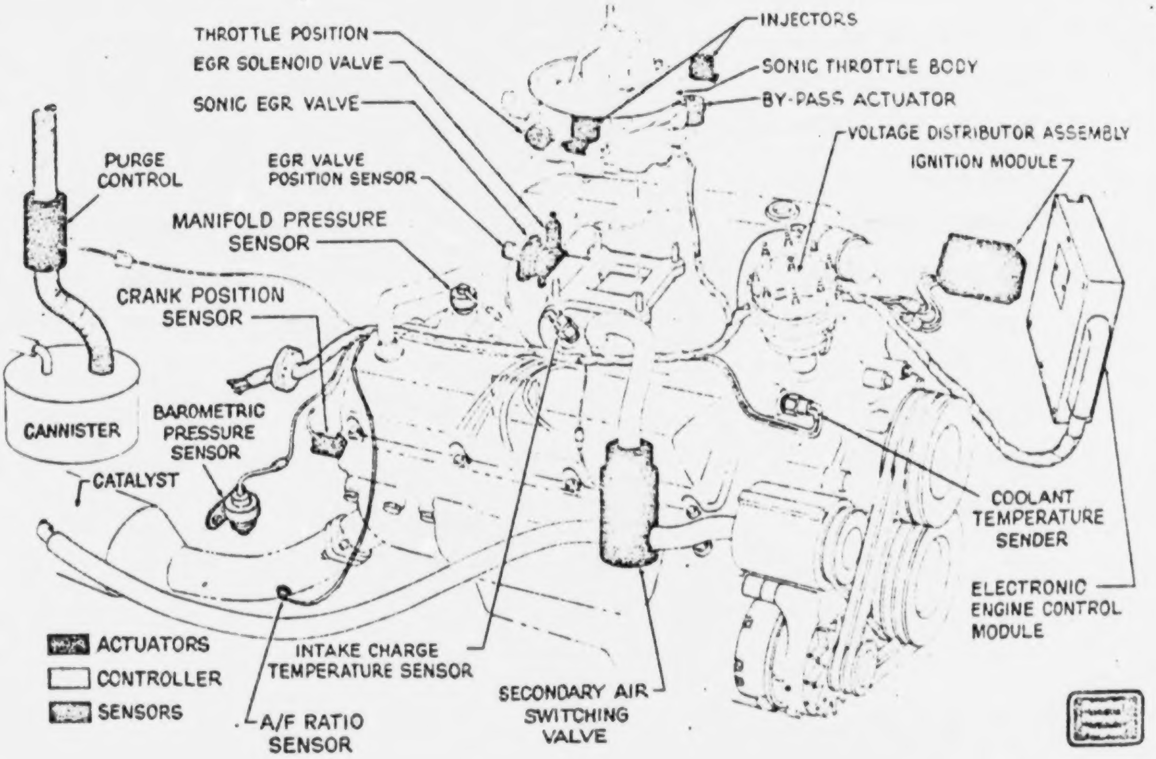
37.6 Transducers and Sensors

Cost Methodology. The learning curve analysis was used in these units.

37.7 Applications

The engine applications are similar except for the number of injectors.

ELECTRONIC ENGINE CONTROLS


THROTTLE POSITION
EGR SOLENOID VALVE
SONIC EGR VALVE
INJECTORS
SONIC THROTTLE BODY
BY-PASS ACTUATOR
VOLTAGE DISTRIBUTOR ASSEMBLY
IGNITION MODULE
PURGE CONTROL
EGR VALVE POSITION SENSOR
MANIFOLD PRESSURE SENSOR
CRANK POSITION SENSOR
CANNISTER
BAROMETRIC PRESSURE SENSOR
CATALYST
COOLANT TEMPERATURE SENDER
ELECTRONIC ENGINE CONTROL MODULE
ACTUATORS
CONTROLLER
SENSORS
INTAKE CHARGE TEMPERATURE SENSOR
SECONDARY AIR SWITCHING VALVE
A/F RATIO SENSOR

OEM COSTS--8-CYLINDER SYSTEM

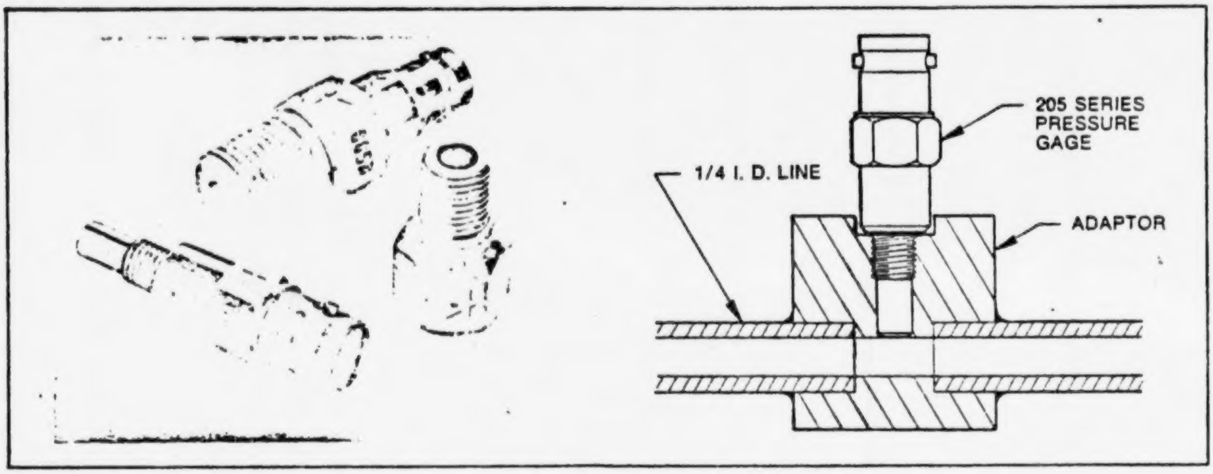
	Industry Estimates			Projected Estimates	
Quantity	5 K	200 K	500 K	1,000 K	5,000 K
Injectors	$ 56.00	$ 40.00	$ 32.00	$ 29.25	$ 23.74
O_2 Sensor	6.00	4.50	2.36	2.16	1.75
ECU	75.00	45.00	45.00	41.13	33.39
Air Temperature	1.75	1.75	1.25	1.14	.93
H_2O Temperature	1.75	1.75	1.25	1.14	.93
Throttle Switch	3.00	3.00	2.30	2.10	1.71
Fuel Pump Assembly	15.00	15.00	12.00	10.97	8.90
Fuel Pressure Regulator	3.00	2.90	2.57	2.35	1.91
Fast Idle Valve	5.00	3.51	2.00	1.83	1.48
Throttle Body	10.00	8.78	5.00	4.57	3.71
Air Solenoid Valve	4.00	3.25	2.00	1.83	1.50
Fuel Filter	3.50	2.00	1.00	.91	.74
Fuel Rail	8.50	6.00	5.00	4.57	3.71
Speed Sensor	1.50	1.00	.75	.69	.56
Intake Manifold					
Wiring Harness	25.20	10.00	5.00	4.57	3.71
	$219.20	$148.44	$119.48	$109.21	$ 88.67

Sundstrand Data Control, Inc.
Subsidiary of Sundstrand Corporation

KISTLER Series

PIEZOTRON©
U.S. Patent No. 3,569,747

Hydraulic Pressure Gages



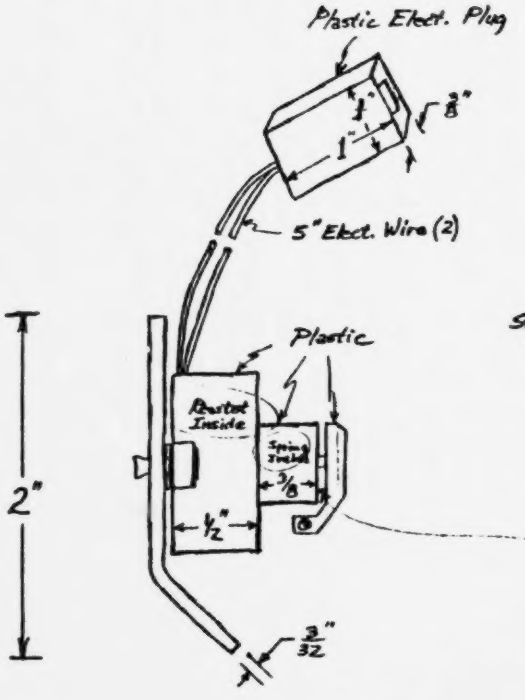
Features

- RUGGED & RELIABLE—
  100,000,000 CYCLES
- SMALL SIZE—MOUNTS IN 1/4" LINES
- HIGH LEVEL OUTPUT—
  5 VOLTS FULL SCALE
- HIGH RESOLUTION
  MEASURES 10,000 to 0.5 psi, or
  1,000 to 0.05 with one sensor
- EASE OF INSTALLATION

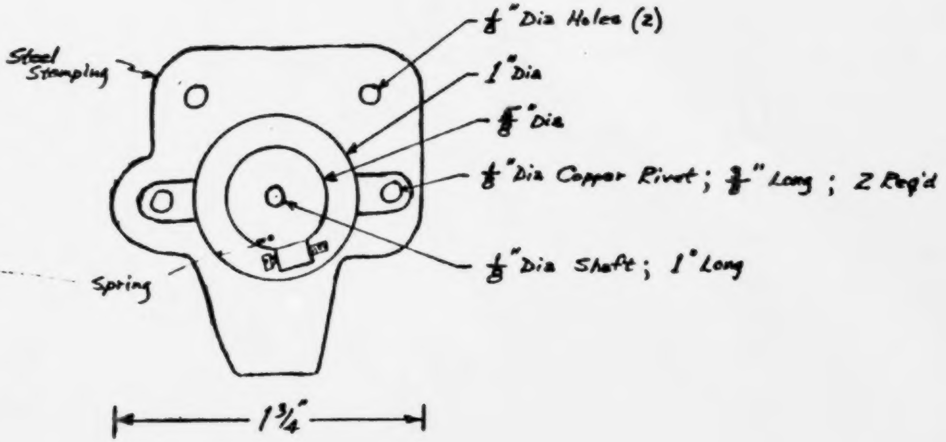
The 205 Series Hydraulic Pressure Gage was specifically designed FOR DYNAMIC HYDRAULIC PRESSURE MEASUREMENTS. Practically indestructible, with a hardened 17-4 PH stainless steel body, and tested for 100,000,000 cycles, they combine the stability, wide frequency response and high resolution of a quartz element with a high level output signal, compatible with most readout equipment. This is made possible with our revolutionary Piezotron concept whereby a miniature circuit is built into the housing to convert the quartz piezoelectric-generated charge to a robust, low impedance voltage.

UNLIKE A STRAIN GAGE, the 205 Gages are designed for flush mounting in lines as small as 1/4" I.D., where its sensing surface "sees" the pressure changes you need to know, thereby eliminating cavitation effects. A truly dynamic instrument, with natural frequency of more than 250,000 Hz, IT DOESN'T MISS HALF YOUR DATA. A 25,000 to 1 signal-to-noise ratio with an output of 5 volts full scale allows you to read your whole dynamic pressure spectrum, accurately, with one sensor.

Designed to Measure Pump Ripple—Hydraulic Line Surges
Pipe Line Pulsations—Actuator Performance—Fuel Injection Pressure
Brake Systems Efficiency—Hydraulic Controls—Tubing Endurance


Plastic Elect. Plug
1/2"
1"
3/8"
5" Elect. Wire (2)
Plastic
Reostat Inside
Spring Inside
3/8
1/2"
2"
3/32"

THROTTLE POSITION SENSOR
(APPROX. FULL SCALE)


Steel Stamping
Spring
1/8" Dia Holes (2)
1" Dia
5/8" Dia
1/8" Dia Copper Rivet; 3/8" Long; 2 Req'd
1/8" Dia Shaft; 1" Long
1 3/4"

MAIN COMPONENT LIST

① STEEL MOUNTING PLATE (3/32" thick; 4 - ~1/8" holes; stamping)
② PLASTIC BODY (houses Reostat in large portion, Spring in smaller portion)
③ PLASTIC HUB + ARM (with threaded portion for adjustment screw); pressed on splined shaft)
④ STEEL ADJUSTMENT SCREW
⑤ STEEL RETURN SPRING
⑥ REOSTAT
⑦ STEEL SHAFT (splined on end for Arm/Hub; Reostat arm mounted on opposite end)
⑧ 2 - COPPER RIVETS
⑨ 2 - 5" ELECTRICAL WIRES WITH ATTACHED PLASTIC PLUG

DEVELOPMENT OF USEFULLY ACCURATE METHODOLOGIES FOR ESTIMATING MANUFACTURING COSTS OF AUTOMOTIVE COMPONENTS

General Discussion

It must be recognized as a reality that the manufacturing cost of a component can never be pinpointed.

Vendor qualifications (quality, delivery performance, second-source considerations) contribute to variation in the cost of the component. Internal operations also contribute to the variation (method changes, scrap rates, tolerance adjustments).

The point being made is that any estimate of a component's cost is subject to some error.

The question then becomes, "How big an error is allowable?" ("Can it be accepted?")

COST VERSUS WEIGHT METHODOLOGY

Logic dictates that, all things being equal, the manufacturing costs of parts of a given material should bear some rational relationship to their weights: there is more material in the heavier piece; its very weight or size should tend to slow down the rate at which it can be processed.

Of course all things are not equal. One piece is more complex than another, requiring additional operations, thereby pushing up its cost. And this means that although, in aggregate, a good correlation between weight and cost does exist, the estimated cost of a single item based on its weight alone is subject to a measurable degree of probable inaccuracy.

To clarify a bit the laws of inaccuracy (generally called laws of probability) consider the following synthetic example:

Suppose a formula says that 95% of the one-pound pieces cost $1.00 plus or minus $.20.

1. This means that were you to select one piece, weigh it, find that it weighed one pound and so cost it at $1.00, you could be incorrect by $.20.

2. The very same formula inherently implies that were 25 different one-pound pieces priced, the total would be in error by only plus or minus $1.00, since some would err on the high side and others on the low.

3. The average per-piece error decreases by the square root of the number of pieces averaged.

WEIGHT-COST CORRELATION FORMULAE

The Manufacturing Costs used in the data base are, for the most part, derived from mathematical equations that relate the weight of a piece to its Manufacturing Cost. The equations are all linear and of the familiar slope-and-intercept form $y = ax + b$.

The equations, the development of which is described in subsequent text, are given in Exhibit 1.

Exhibit 1

FORMULAE FOR ESTIMATING THE MANUFACTURING COST OF A PART WHEN ITS WEIGHT IS KNOWN

Material	Formula Modifiers		$ Cost Equals Wgt Lbs	x	Slope Factor (a)	+	Intercept (b)
Stamped Steel	Simple Parts:	up to 4 lbs.*	(W	x	$ .233)	+	$.030
Stamped Steel	Medium Parts:	up to 4 lbs.*	(W	x	.30)	+	.080
Stamped Steel	Complex:	up to 4 lbs.*	(W	x	.367)	+	.13
Steel Wire			(W	x	.439)	+	.034
Aluminum			(W	x	.238)	+	.461
Plastic	Light:	up to 0.1 lbs.	(W	x	2.03)	+	.013
Plastic	Heavy:	over 0.1 lbs.	(W	x	.438)	+	.102
Die Cast Zinc			(W	x	1.19)	+	.144
Rubber			(W	x	1.109)	+	.014

*Beyond this limit, engineering estimates should be made.

DEVELOPMENT OF THE WEIGHT-COST CORRELATION FORMULAE

Data Sources

Three separate sets of cost estimations, each from a different source, were used in arriving at the equations presented. On all three, the cost of a part was established by the universally-used industrial engineering technique: an experienced machine tool engineer, having a wide background knowledge of processing methods and rates and having information on the dimensions and configuration of a given piece, can predict its cost within close limits.

The three sources:

A. Pioneer Engineering and Manufacturing Corporation report, February 1976; Report No. DOT-HS-5-01081.

B. Budd Minicar study (DOT/HTSA).

C. Rath & Strong report (DOT/TSC 1067).

Computation Procedures - General

Each set of data was analyzed separately. The three analyses were compared and found to be in good agreement, with some isolated instances of parts not fitting the overall weight-cost correlation pattern. These relatively few significant deviations were individually examined and virtually all were rationally explained. (Main causes were (1) erroneous classification of assemblies as parts and (2) heavier steel parts, over 5 pounds, do not exhibit a close enough relationship between weight and cost.)

The three analyses were then amalgamated into one best solution, resulting in the formulae presented previously in Exhibit 1.

COMPUTATION PROCEDURE - SPECIFIC EXAMPLES

Example 1 - Stamped Steel - Pioneer Data

(As described in the referenced Pioneer report, a 1975 Chevelle Coupe was completely dismantled and a detailed analysis made of each component; weights were recorded and manufacturing costs were estimated, using "procedures and techniques adapted from the automotive industry;" with 350,000 units per year and September 1, 1975 labor rates and material cost as a base.)

The weight and cost figures given were first graphed into a scatter plot.

Visual analysis of the plotted points indicated that while a weight-cost correlation clearly existed, the points were not normally distributed about any "best-fit" central line. In other words, two families of parts existed--a so-called bimodal distribution of "simple" and "complex" parts.

Exhibit 2, which covers the weight range from 0 to 1.5 pounds, most clearly demonstrates this bimodal characteristic. The same distinctness of families pertains up to 4 pounds; beyond this weight the correlation of weight and cost becomes too weak to be useful.

Two linear regression lines are required; one for the "simple" family and one for the "complex," as shown in Exhibit 3.

Exhibit 4 displays the 0-3.99 pounds raw data from the Pioneer report and also the part-by-part comparison with them and the values derived from the best fit lines. As can be seen, 52 parts are involved which, on a one-each basis, are estimated to cost $14.33, against which the weight-cost correlation equations give an estimate of $14.60; a difference in total of only $.27 and the largest single part error is $.13.

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Exhibit 2

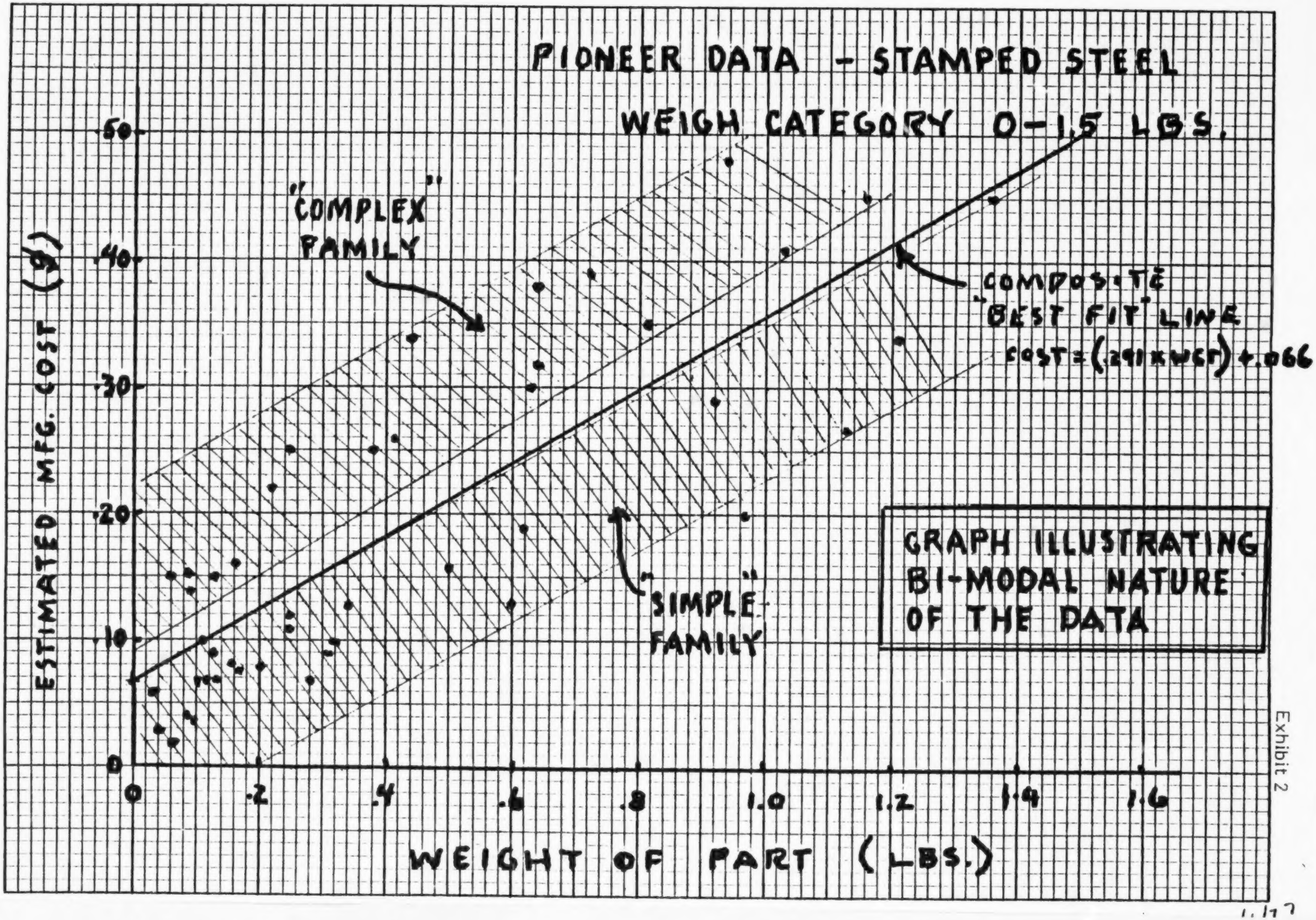


Exhibit 3

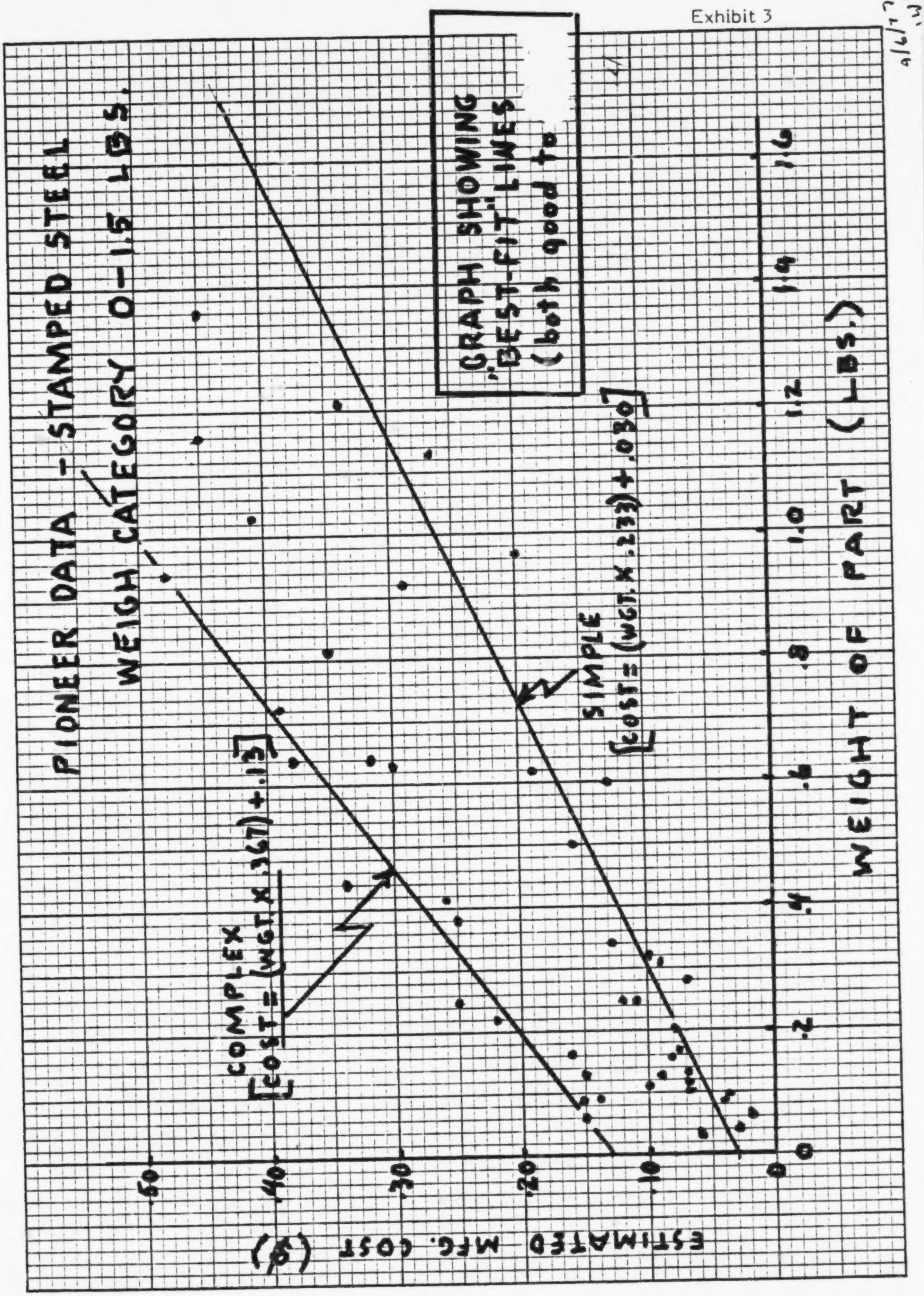

PIONEER DATA - STAMPED STEEL
WEIGH CATEGORY 0-1.5 LBS.
GRAPH SHOWING "BEST-FIT" LINES (both good to
COMPLEX [COST = (WGT. X .367) + .13]
SIMPLE [COST = (WGT. X .233) + .030]
ESTIMATED MFG. COST ($)
0
.10
.20
.30
.40
.50
WEIGHT OF PART (LBS.)
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6

Exhibit 4

STAMPED STEEL--COMPARISON OF PIONEER ESTIMATES AND WEIGHT-COST EQUATIONS VALUES (0-3.99 POUNDS)

Pioneer Data (Ranked by Wgt) Lbs.	Pioneer Data (Ranked by Wgt) $	Class* of Part	Weight-Cost Equation $	Weight-Cost Equation Diff. (Over)
.03	$.06	S	$.04	$-.02
.04	.03	S	.04	.01
.06	.02	S	.04	.02
.09	.04	S	.05	.01
.09	.04	S	.05	.01
.10	.07	S	.05	-.02
.11	.10	S	.06	-.04
.12	.07	S	.06	-.01
.13	.07	S	.06	-.01
.13	.09	S	.06	-.03
.16	.08	S	.07	-.01
.16	.08	S	.07	-.01
.20	.08	S	.08	-
.25	.12	S	.09	-.03
.25	.11	S	.09	-.02
.28	.07	S	.10	.03
.31	.09	S	.10	.01
.32	.10	S	.10	-
.34	.13	S	.11	-.02
.50	.16	S	.15	-.01
.60	.13	S	.17	.04
.62	.19	S	.17	-.02
.94	.29	S	.25	-.04
.97	.20	S	.26	.06
1.13	.27	S	.29	.02
1.21	.34	S	.31	-.03
1.88	.45	S	.47	.02
1.97	.55	S	.49	-.06
2.16	.46	S	.53	.07
2.38	.64	S	.58	-.06
2.81	$ .55	S	$ .68	$ .13
2.81	.55	S	.68	.13
Subtotal				
	$6.23	S	$6.35	$ .12
.06	.15	C	.15	-
.09	.14	C	.16	.02
.09	.15	C	.16	.01
.13	.15	C	.18	.03
.16	.16	C	.19	.03
.22	.22	C	.21	-.01
.25	.25	C	.22	-.03
.38	.25	C	.27	.02
.41	.26	C	.28	.02
.44	.34	C	.29	-.05
.63	.30	C	.36	.06
.64	.38	C	.36	-.02
.64	.32	C	.36	.04
.72	.39	C	.39	-
.81	.35	C	.43	.08
.94	.48	C	.47	-.01
1.75	.91	C	.77	-.14
1.91	.82	C	.83	.01
2.25	.89	C	.96	.07
2.93	1.19	C	1.21	.02
Subtotal				
	$8.10	C	$8.25	$ .15
Grand Total				
	$14.33		$14.60	$ .27

*Simple = S Complex = C

Example 2 - Plastic

The data on plastic parts given in the Pioneer report was analyzed in a manner similar to that described in Example 1.

Here, the scatter-plotted points, Exhibit 5, showed a clear delineation between the lighter (up to 0.1 pounds) and the heavier parts. Two best-fit lines describe closely the relations between weight and estimated cost.

Exhibit 6 presents the raw data and the comparable mathematically-generated values. On a one-each basis, both methods give a total of $3.69 for the 19 pieces involved, and the greatest individual deviation is $.07.

Exhibit 5

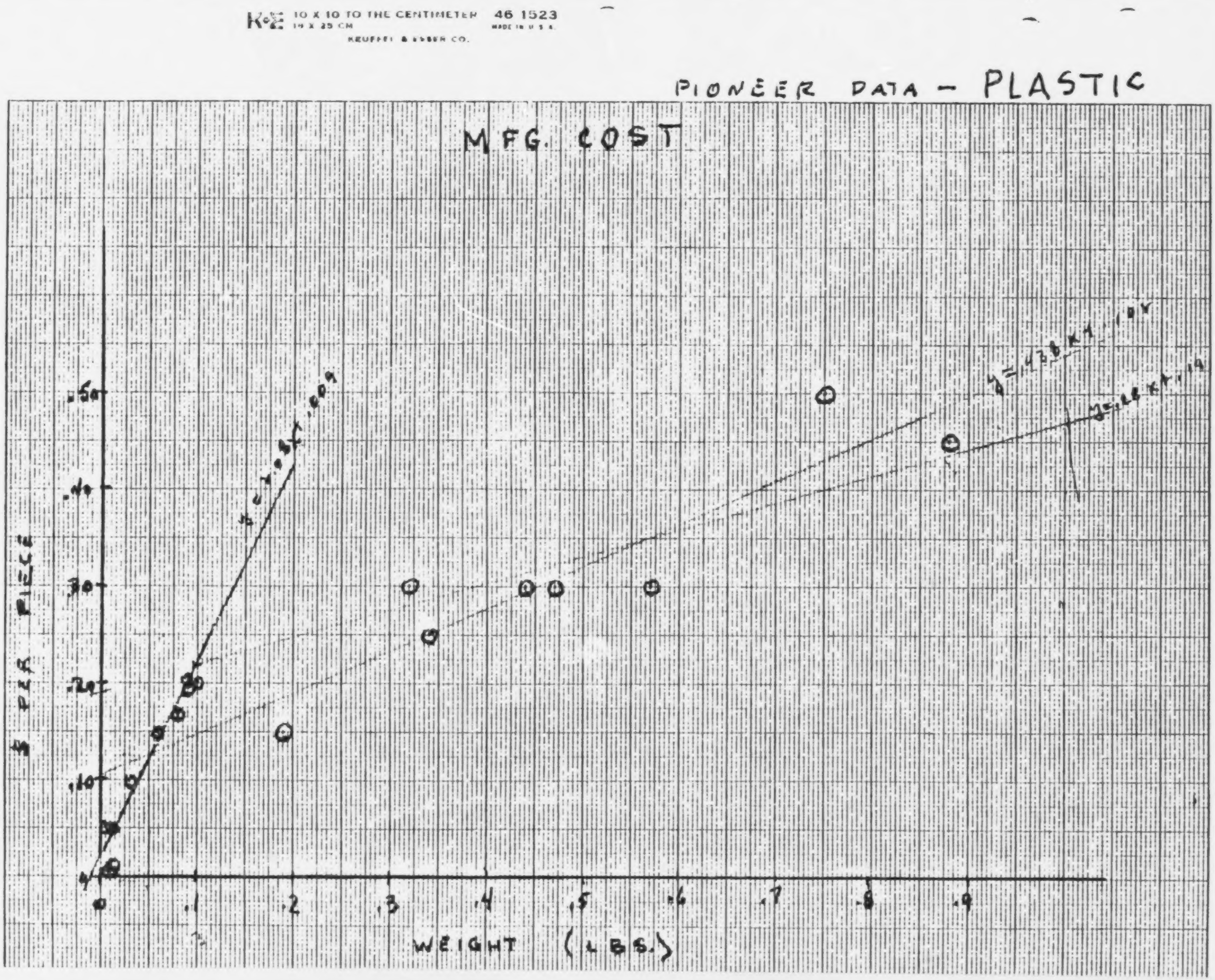
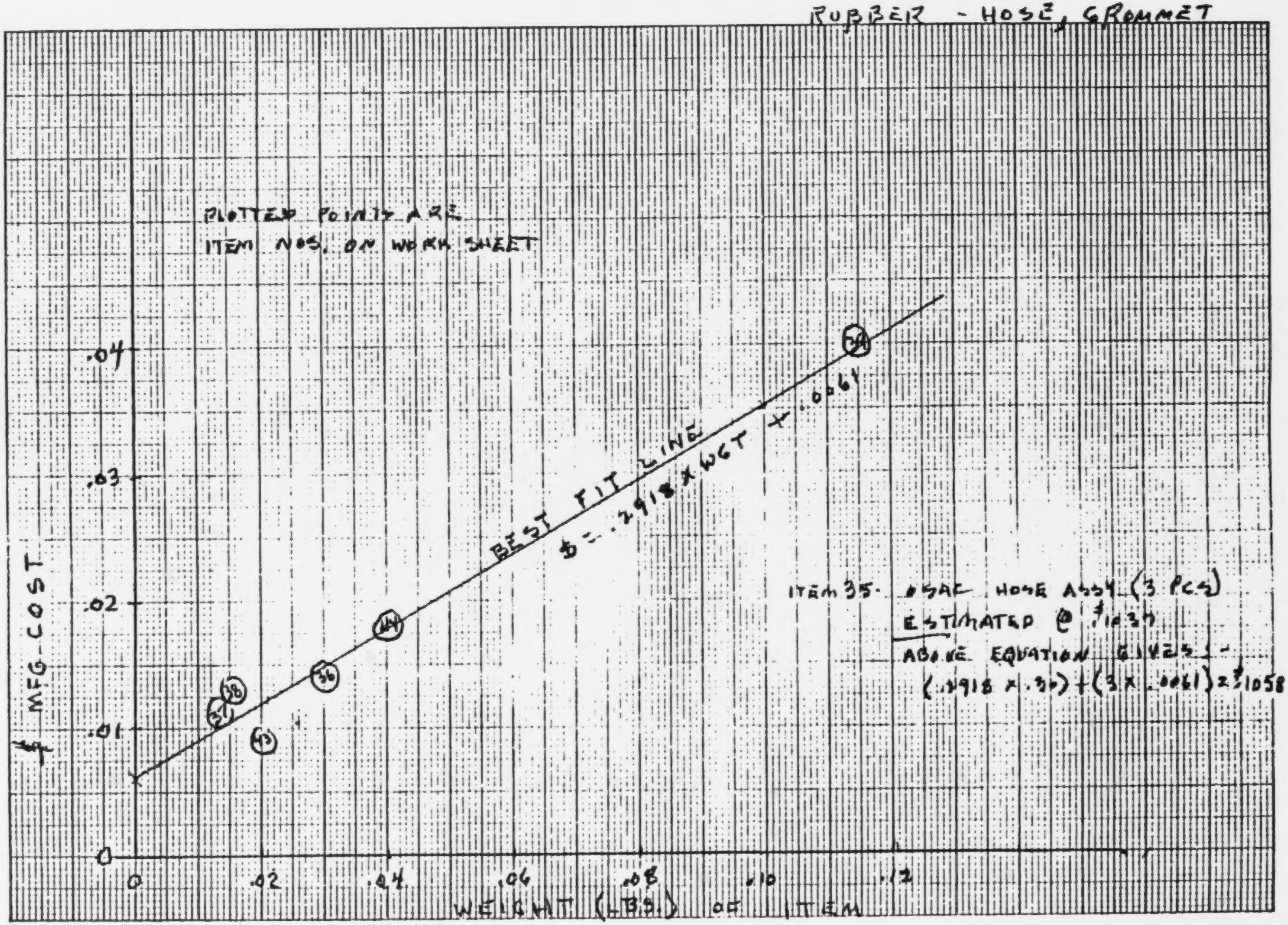

K+E 10 X 10 TO THE CENTIMETER 46 1523
18 X 25 CM MADE IN U.S.A.
KEUFFEL & ESSER CO.
PIONEER DATA - PLASTIC
MFG. COST
$ PER PIECE
.10
.20
.30
.40
.50
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
WEIGHT (LBS.)
y = 1.95 x 1.009
y = .428 x .104
y = .48 x .14

Exhibit 6

PLASTIC--COMPARISON OF PIONEER ESTIMATES AND WEIGHT-COST EQUATIONS VALUES

Pioneer Data Lbs.	$	Weight Class	Weight-Cost Equation $	$ Diff. (Over)
.005	$ .005	Light	$ .02	$ .015
.005	.05	Light	.02	-.03
.01	.005	Light	.03	.025
.01	.01	Light	.03	.02
.01	.05	Light	.03	-.02
.03	.10	Light	.07	-.03
.06	.15	Light	.14	-.01
.08	.17	Light	.18	.01
.09	.20	Light	.20	-
.09	.20	Light	.20	-
.10	.20	Light	.22	.02
		Subtotal		
	$1.14	Light	$1.14	-
.19	.15	Heavy	.19	.04
.32	.30	Heavy	.24	-.06
.34	.25	Heavy	.25	-
.44	.30	Heavy	.29	-.01
.47	.30	Heavy	.31	.01
.57	.30	Heavy	.35	.05
.75	.50	Heavy	.43	-.07
.88	.45	Heavy	.49	.04
		Subtotal		
	$2.55	Heavy	$2.55	-
		Grand Total		
	$3.69		$3.69	-

REFERENCE
RUBBER - HOSE, GROMMET



ITEM 35. #SAE HOSE ASSY (3 PCS)
ESTIMATED @ $.1037
ABOVE EQUATION GIVES :-
(.2918 x .30) + (3 x .0061) = $.1058

Budd Company Report 0323-1 (DOT-HS-5-01215)

RESEARCH SAFETY VEHICLE PRODUCIBILITY AND COST STUDY FOR MINICARS, INC.--November 5, 1976

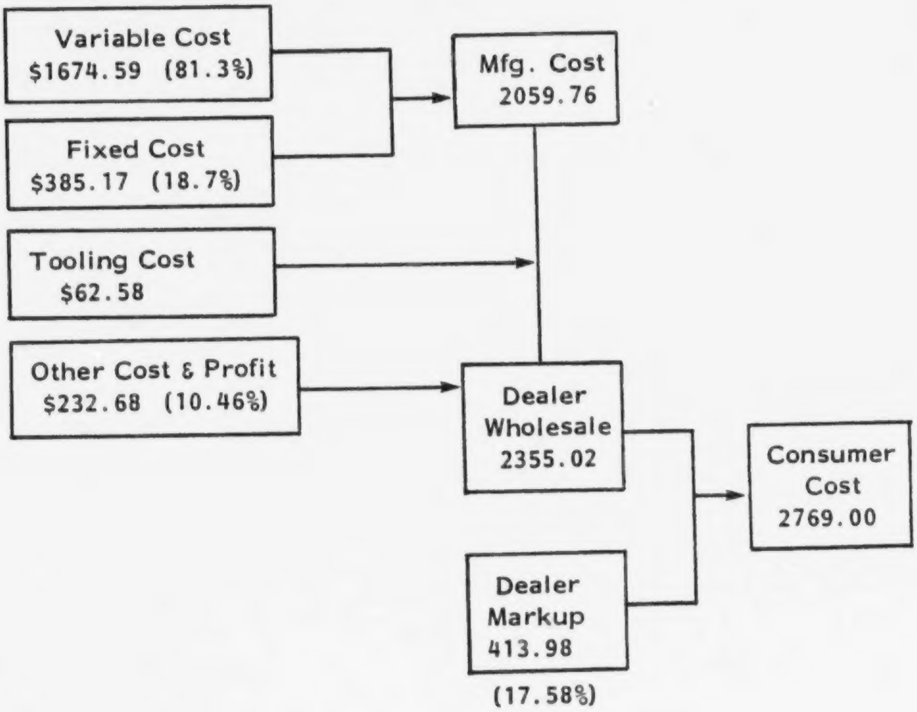
Volume Basis - 300,000 Units/Year

All Costs in 1975 Dollars

Costing Data Developed from 1975 Pinto.

→ <Data Obtained from NHTSA Contract HS-5-00153>

1975 Pinto Cost Data:


Variable Cost
$1674.59 (81.3%)
Fixed Cost
$385.17 (18.7%)
Tooling Cost
$62.58
Other Cost & Profit
$232.68 (10.46%)
Mfg. Cost
2059.76
Dealer
Wholesale
2355.02
Dealer
Markup
413.98
(17.58%)
Consumer
Cost
2769.00

Budd Company (Continued)

Baseline data generated by Pioneer Engineering and Manufacturing Corporation, DOT-HS-5-01153.

Each part of the Minicar reviewed as to number of operations to form it and the tooling costs--then compared to similar Pinto parts and comparative costs established.

In-depth study of Pinto data made to accommodate manufacturing sequence differences between Pinto and Minicar.

BUDD FORMULAE

24 GA. CRS - \$/Pc = \$.10 + (\$.25) WGT

48 GA. CRS - \$/Pc = \$.20 + (\$.29) WGT

PIONEER FORMULAE

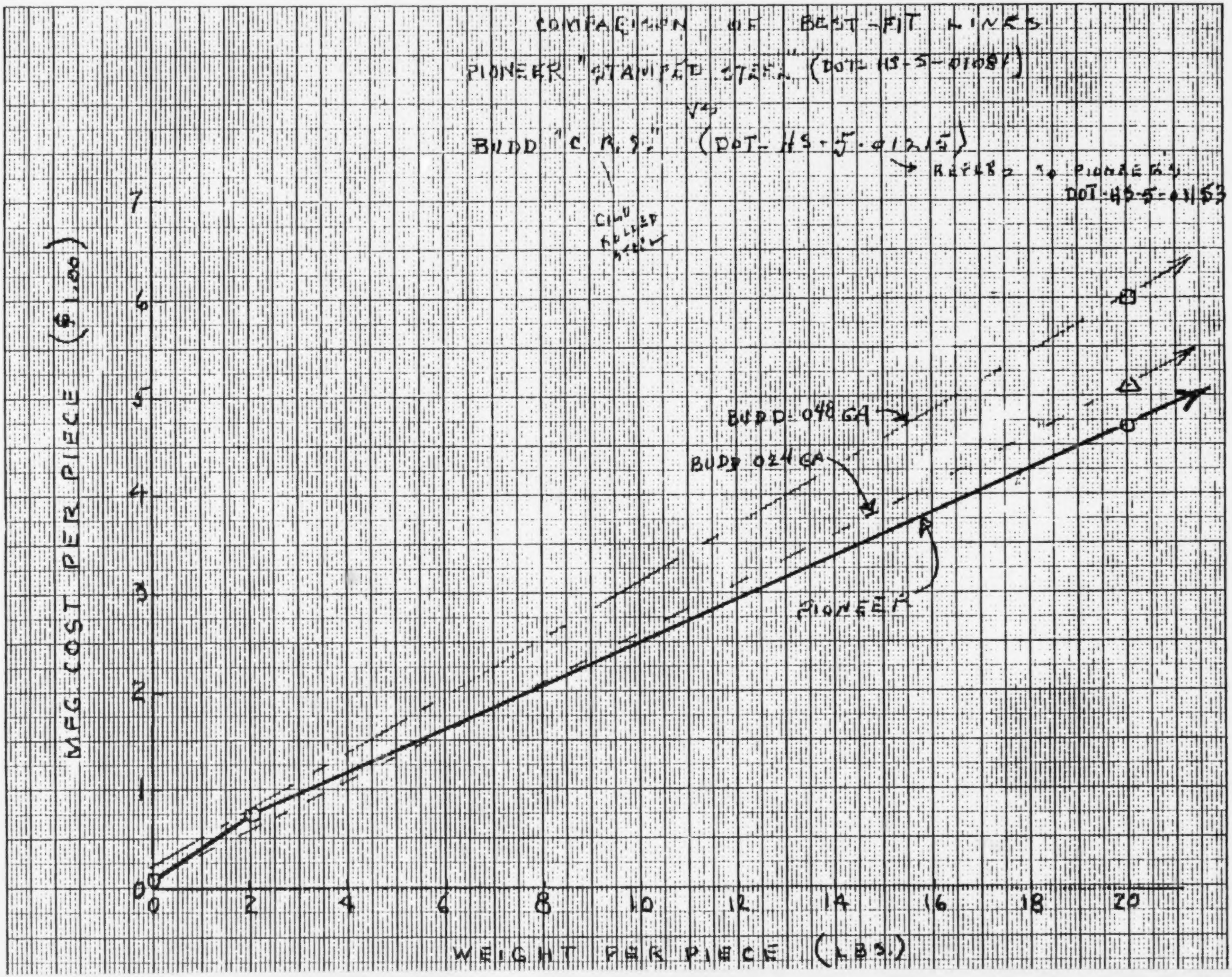
STAMPED STEEL

0 - 2#	$y = .07 + .32x$
2# - 5#	$y = .75 + 0x$
5# - 40#	$y = .14 + .22x$

Final Revision: --

0 - 2#	$y = .08 + .33x$
2^{+}#- 40#	$y = .30 + .22x$

GRAPH PAPER ® PRINTED IN U.S.A.



PIONEER ENGINEERING & MANUFACTURING CORPORATION

February 1976

DOT-HS-5-01081

(Note: This one, based on Intermediate Type Car, is not the same one referred to by Budd, which spoke of a 1975 Pinto.)

1975 Chevelle Coupe

Car dismantled, detailed analysis of components made; weights recorded; manufacturing costs estimated.

"Cost estimating procedures and techniques adapted from the automotive industry."

(Gives bibliography of other studies using same estimating practices.)

Final Assembly Labor = 24 Hours

Volume - 350,000 Units/Year

September 1, 1975 Labor Rates and Materials Costs

Graphical analysis of the "Stamped Steel" data in the Pioneer report DOT-HS-5-01081 leads to these observations and conclusions:

1. A simple linear regression, ("best fit") line relating piece cost and piece weight is not a practical model.

2. The data are not scattered about this central line in a normal distribution pattern. Rather, they form a Bi- or Multi-Modal distribution.

3. This Multi-Modal character of the data is a natural reflection of the various complexities of the pieces (complexity here implies number and types of operations as well as skeleton scrap at blanking and piercing.

4. Three levels of complexity classification are recommended:

   (a) Simple

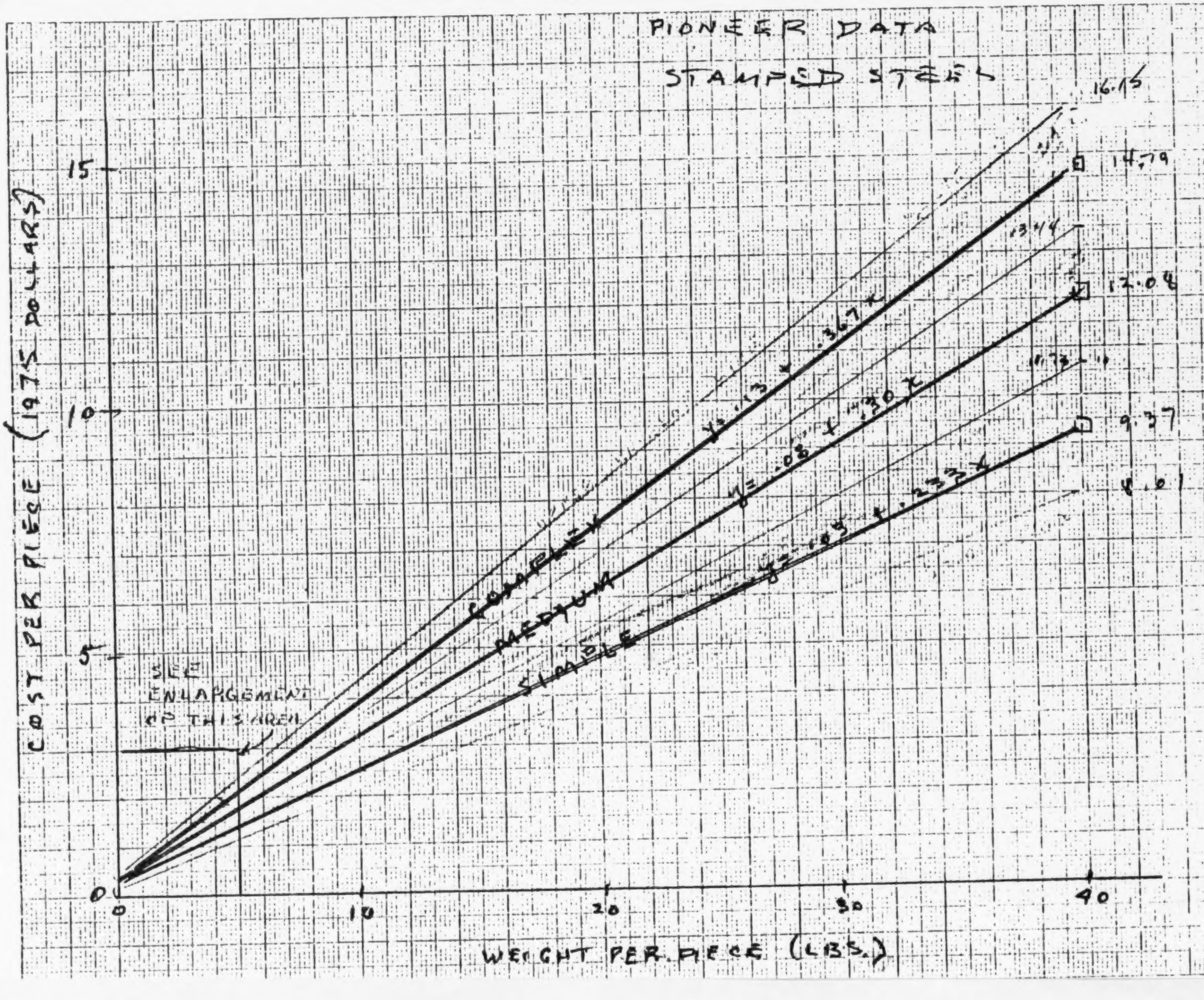
   $/Pc = $.03 + ($.233 x lbs.)

   (b) Medium

   $/Pc = $.08 + ($.30 x lbs.)

   (c) Complex

   $/Pc = $.13 + ($.367 x lbs.)

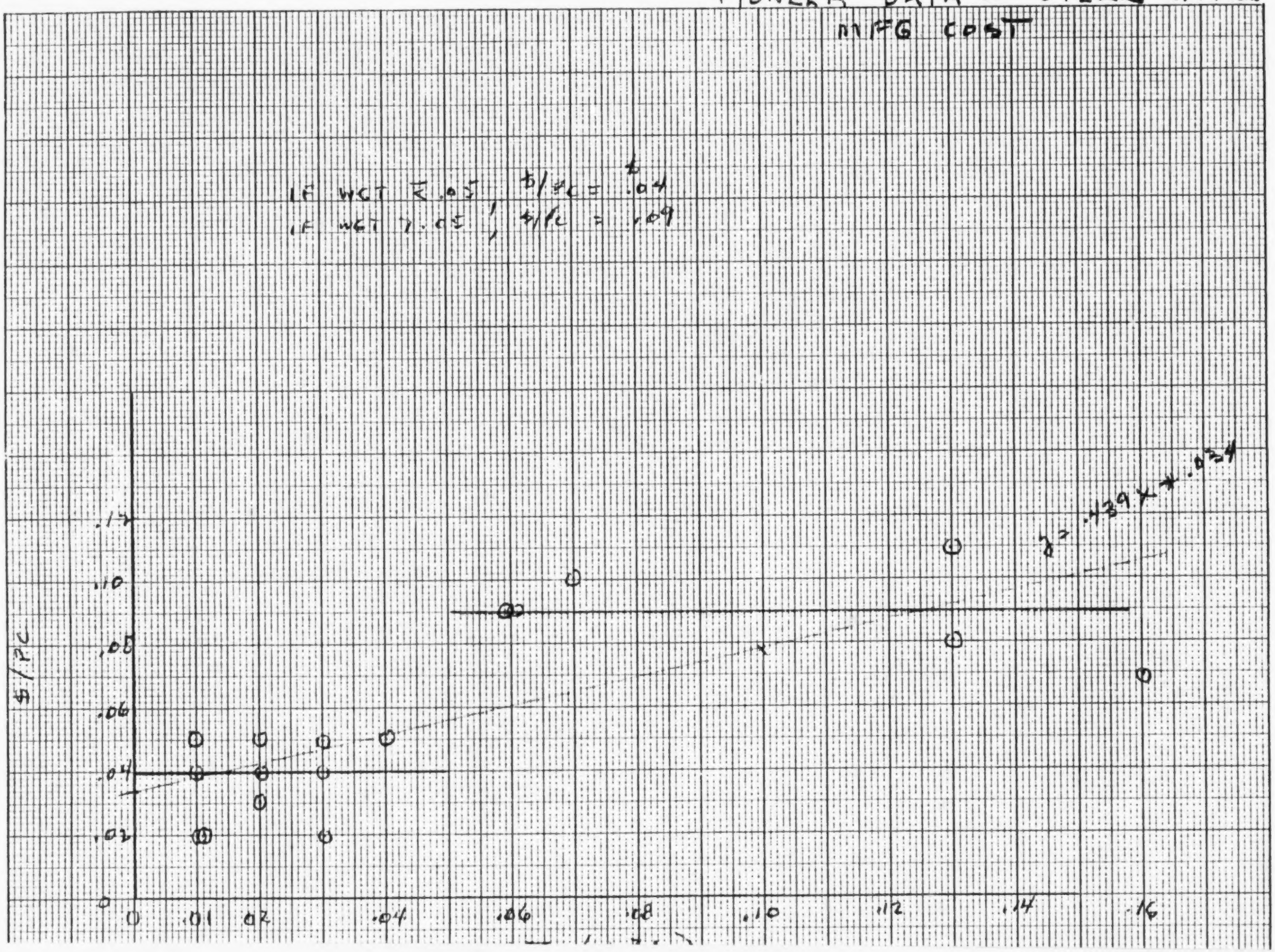


PIONEER DATA

STAMPED STEEL

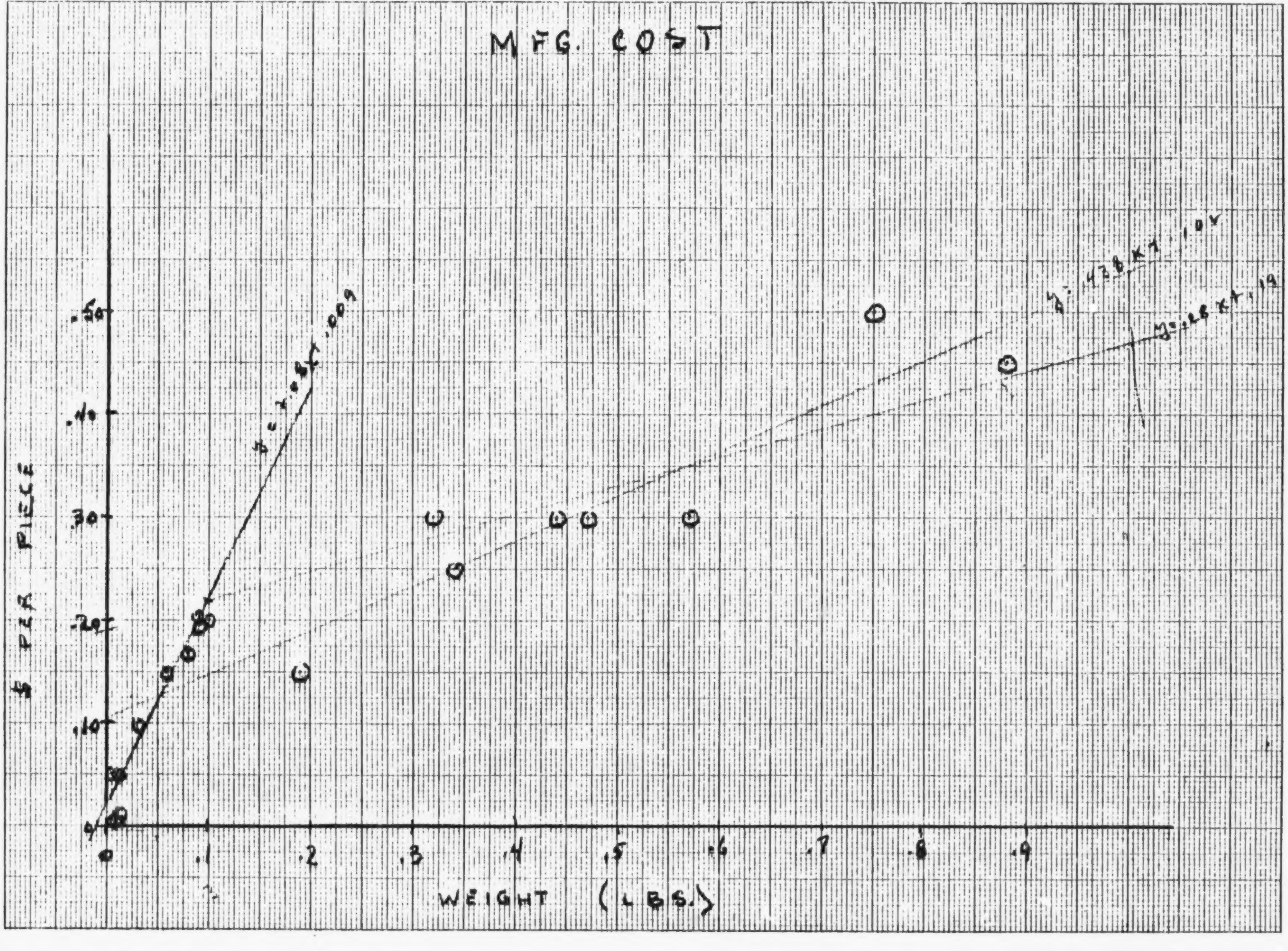
NO. 318 20 DIVISIONS PER INCH BOTH WAYS. 150 BY 200 DIVISIONS.
codex GRAPH PAPER® IN STOCK DIRECT FROM CODEX BOOK CO., NORWOOD, MASS.
PRINTED IN U.S.A.

PIONEER DATA — STEEL WIRE
MFG COST



K&E 10 X 10 TO THE CENTIMETER 46 1523
18 X 25 CM MADE IN U.S.A.
KEUFFEL & ESSER CO.

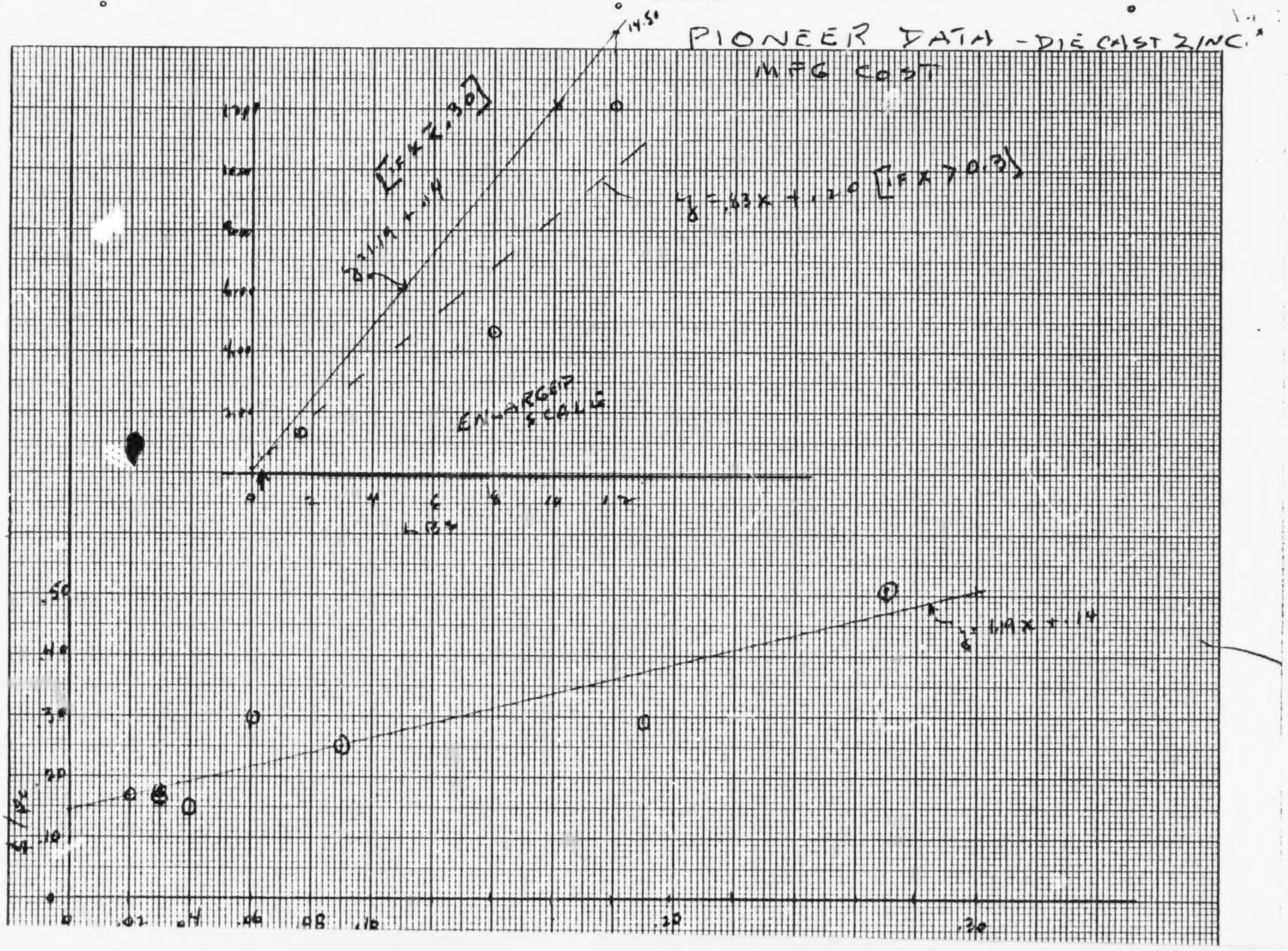
PIONEER DATA - PLASTIC



NO. 316 20 DIVISIONS PER INCH BOTH WAYS. 150 BY 200 DIVISIONS. codex GRAPH PAPER® IN STOCK DIRECT FROM CODEX BOOK CO., NORWOOD, MASS. 02062 PRINTED IN U.S.A.

PIONEER DATA - DIE CAST ZINC

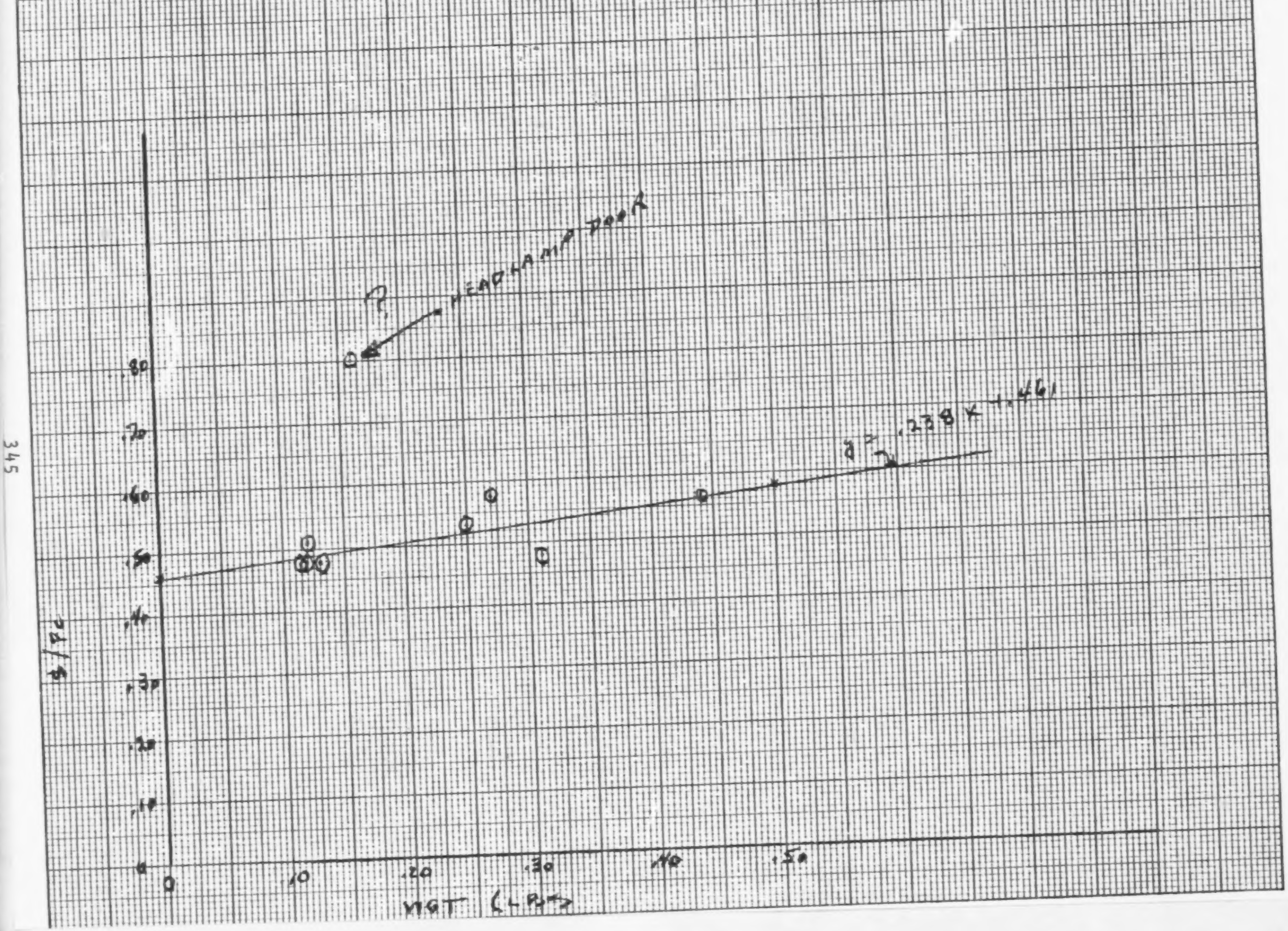
MFG COST



GRAPH PAPER

PIONEER DATA – ALUMINUM

MFG. COST



INTRODUCTORY SUMMARY TO COVER ITEMS 10-16

CATALYTIC CONVERTERS--GENERAL

There are seven types of catalytic converters to be considered.

Categorized by function, they fall into four classes: 3-way, oxidation, reduction, and start. Categorized by physical configuration, there are only two classes: in-line cylindrical and under-floor pan.

	Configuration Class	
Catalyst Function Class	In-Line Cylindrical	Under-Floor Pan
Monolithic 3-Way	X	
Monolithic Oxidation	X	
Monolithic Reduction		X
Monolithic Start	X	
Pelleted Oxidation		X
Pelleted Reduction		X
Metallic Reduction	X	

For purposes of cost estimating, the configuration classification is by far the more applicable, and has been used in the methodology underlying the sections following.

The first section, "Monolithic 3-Way Catalysts," presents in detailed fashion the step-by-step logic employed in the estimations. Subsequent sections refer to this logic where applicable, and expand only on pertinent details.

In each case, an equation is provided by which, when the catalytic content and the volume are specified, the estimated plant manufacturing cost and retail price equivalent can be calculated. These equations are embodied in forms A, B, and C.

1. CALCULATION OF THE COST PER GRAM OF CATALYTIC COMPOUNDS

1.1 Conversion Factors - Weight

The material prices are typically quoted in varying units of weight. Herewith is a list of factors by which to convert each to grams.

Avoirdupois pounds x 453.5924 = grams
Avoirdupois ounces x 28.3495 = grams
Troy pounds x 373.248 = grams
Troy ounces x 31.104 = grams

1.2 Conversion Factors - Volume

Cubic feet x 1728 = cubic inches
Square feet x 144 = square inches

1.3 Cost Per Gram of a Composition of Materials - (Exact Method)

1.3.1 To calculate the compound cost in dollars per gram, use the following format:

	Quoted Price		Conversion to $/Gram		Pro-Portion in	Compound
Material	$	Unit	Conv. Factor	$/Gram	Compound	$/Gram
A-1	B	C	D	E	F	H
A-2						
A-3						
Etc.						
Total Compound					G 1.000	J

A-1, A-2, Etc. - List ingredients
B & C - Quoted $ and units in which quoted
D - Appropriate conversion factor from 1.1
E - Divide B by D
F - List proportion as decimals (10% = 0.10)
G - Sum of column F must equal 1.000
H - Multiply F by E
J - Sum of column H equals compound cost per gram

1.3.2 Example 1

What is the cost per gram of a compound which contains 2% rhemium; 0.4% ruthenium; 3% nickel; and in which the platinum-to-rhodium ratio is 25: 1?

Solution -
Rhenium = .020
Ruthenium = .004
Nickel = .030

Subtotal = .054

Remainder = 1.000-.054 = .946

Platinum $\frac{25}{25+1} \times .946 = .910$

Rhodium $\frac{1}{25+1} \times .946 = .036$

Total 1.000

Material	Quoted Price $	Unit	Conversion to $/Gram Factor	$/Gram	Pro-Portion	Compound $/Gram
Platinum	167.00	T. oz	31.104	5.369	.910	4.886
Rhodium	455.00	T. oz.	31.104	14.628	.036	.527
Rhenium	775.00	Av. lb.	453.5924	1.709	.020	.034
Nickel	2.23	Av. lb.	453.5924	.005	.030	-
Total Compound					1.000	5.447

1.4 Cost per Gram of a Composition of Substrate Materials - (Approximation Method)

This short-cut method, within the proportion limits proscribed, will deviate no more than 2% from the exact method described above.

1.4.1 Procedure

1. Calculate the cost per gram as if platinum and rhodium were the only ingredients (Pt + Rh = 100%).

2. Multiply this by the proportion represented by the sum of platinum and rhodium.

3. Add to this the product of the remaining proportion times $.67.

1.4.2 Example 2

What is the cost per gram of a compound which contains 2% rhenium; 0.4% ruthenium; 3% nickel; and in which the platinum-to-rhodium ratio is 25:1?

1.

Platinum	25 parts	x $5.369	= $134.225
Rhodium	1 part	x 14.628	= 14.628
Totals	26 parts		$148.853

Cost/gram of mix $\frac{148.853}{26}$ = $5.725

2.

Platinum	91.0
Rhodium	3.6%
Sum	94.6%

.946 x $5.725 = $5.416

3. (1.000 - .946) x $.67 = $.036

4. $5.416 + $.036 = $5.452 (answer)

(Compare with $5.447gotten by Exact Method, Example 1, Section 1.3.2.)

1.4.3 Discussion - The short-cut method is made feasible because of two factors:

(a) Platinum and rhodium constitute 84.5% or more of the mixture, and

(b) The unit price of these is much greater than of the other constituents.

1.4.4 Typical Extreme Calculation

Platinum to Rhodium = 2:1 (upper cost ratio)

Platinum & Rhodium	= 84.5%	(lower limit)
Rhenium	= 5.0%	(upper limit)
Ruthenium	= 0.5%	(upper limit)
Nickel	= 10.0%	(upper limit)
	100.0%	

Platinum	$5.369 x 2/3 x .845		= $3.025
Rhodium	14.628 x 1/3 x .845		= 4.120
		Subtotal	$7.145
Rhenium	1.709 x .050		= .085
Ruthenium	2.009 x .005		= .010
Nickel	.005 x .100		= .001
			$7.241

GRAMS OF COMPOUND REQUIRED FOR VARIOUS VOLUMES AND LOADINGS

		LOADING (Gm/Ft^3)									
		1	5	10	15	20	30	40	50	60	70
Volume (in^3)	1	.00058	.00289	.00579	.00868	.01157	.01736	.02315	.02894	.03472	.04051
	10	.00579	.029	.058	.087	.116	.174	.231	.289	.347	.405
	20	.01157	.058	.116	.174	.231	.347	.463	.579	.694	.810
	50	.02894	.145	.289	.434	.579	.868	1.16	1.45	1.74	2.03
	100	.05787	.289	.579	.868	1.16	1.74	2.31	2.89	3.47	4.05
	150	.08681	.434	.868	1.30	1.74	2.60	3.47	4.34	5.21	6.08
	200	.11574	.579	1.16	1.74	2.32	3.47	4.63	5.79	6.94	8.10
	250	.14468	.723	1.45	2.17	2.89	4.34	5.79	7.23	8.68	10.13
	300	.17361	.868	1.74	2.60	3.47	5.21	6.94	8.68	10.42	12.15
	350	.20255	1.01	2.03	3.04	4.05	6.08	8.10	10.13	12.15	14.18
	400	.23148	1.16	2.32	3.47	4.63	6.94	9.26	11.57	13.89	16.20

Grams required = Loading (gm/ft^3) x Volume (in^3) ÷ 1728

Note that the last three ingredients which are presented 15.5% of the total weight added only $.096 to the subtotal cost of Platinum and Rhodium.

The short-cut formula substitutes 15.5% x $.67 = $.104 for the calculated $.096, creating an error of $.008, which is only 0.11% of the total.

2. CALCULATION OF THE WEIGHT OF CATALYTIC COMPOUND USED PER CONVERTER

2.1 Volume used is expressed in cubic inches.

2.2 Loading is spoken of in grams per cubic foot. For ease of calculation this is converted to grams per cubic inch.

1 gram/ft = 1/1728 = .0005787 gm/in

2.3 Total weight equals volume times loading.

weight (grams) = volume (in) x loading (gm/ft) ÷ 1728

2.4 The matrix given in this section gives grams required for various combinations of volume and loading.

3. CALCULATION OF THE COST OF CATALYTIC COMPOUND PER CONVERTER

3.1 Cost per converter equals grams required (Section 2) times the cost per gram of the compound (Section 1).

3.2 For purposes of ready reference, Table is presented giving substrate compound costs at selected values of platinum-rhodium ratio, grams required and total platinum-rhodium content.

3.2.1 Also in Table the following material prices are used:

Platinum	$ 5.369/gm	=	$167/Troy oz.
Rhodium	14.628/gm	=	455/Troy oz.
Rhenium	1.709/gm	=	53/Troy oz.
Ruthenium	2.009/gm	=	62/Troy oz.
Nickel	.005/gm	=	2.23/av. lb.

3.2.2 Intermediate values may be interpolated, or calculated directly.

3.3 Equation for calculating cost of substrate material per converter.

$$\text{COST} = \left\{ (Pp + Pr) \frac{167Pp + 455Pr}{31.103} + \left[1 - (Pp + Pr) \right] .67 \right\} \left\{ \frac{V\ L}{1728} \right\}$$

$$\text{when } \langle Pp + Pr \rangle \geq .845$$

where Pp = Percent Platinum ÷ 100
Pr = Percent Rhodium ÷ 100
V = Volume in cubic inches
L = Loading in grams per cubic foot

COST OF SUBSTRATE MATERIAL PER CONVERTER

% Platinum + % Rhodium = 100%
(See Note 3 if <100%)

Line	Total Grams Substrate Required (Note 1)	Ratio Platinum to Rhodium and Cost Per Gram (Note 2)							
		2:1 $ 8.455	5:1 $ 6.912	7:1 $ 6.526	9:1 $ 6.295	11:1 $ 6.141	19:1 $ 5.832	25:1 $ 5.725	30:1 $ 5.668
1	.029	$ .25	$ .20	$ .19	$ .18	$ .18	$ .17	$ .17	$ .16
2	.058	.49	.40	.38	.37	.36	.34	.33	.33
3	.116	.98	.80	.76	.73	.71	.68	.66	.66
4	.174	1.47	1.20	1.14	1.10	1.07	1.01	1.00	.99
5	.289	2.44	2.00	1.89	1.82	1.77	1.69	1.65	1.64
6	.579	4.90	4.00	3.78	3.64	3.56	3.38	3.31	3.28
7	1.16	9.81	8.02	7.57	7.30	7.12	6.77	6.64	6.57
8	1.74	14.71	12.03	11.36	10.95	10.69	10.15	9.96	9.86
9	2.31	19.53	15.97	15.08	14.54	14.19	13.47	13.22	13.09
10	3.47	29.34	23.98	22.65	21.84	21.31	20.24	19.87	19.67
11	4.05	34.24	27.99	26.43	25.49	24.87	23.62	23.19	22.96
12	5.21	44.05	36.01	34.00	32.80	31.99	30.38	29.83	29.53
13	6.08	51.41	42.02	39.68	38.27	37.34	35.46	34.81	34.46
14	6.94	58.68	47.97	45.29	43.69	42.62	40.47	39.73	39.34
15	7.23	61.13	49.97	47.18	45.51	44.40	42.17	41.39	40.98
16	8.10	68.49	55.99	52.86	50.99	49.74	47.24	46.37	45.91
17	9.26	78.29	64.01	60.43	58.29	56.87	54.00	53.01	52.49
18	10.13	85.65	70.02	66.11	63.77	62.21	59.08	57.99	57.42
19	11.57	97.82	79.97	75.51	72.83	71.05	67.48	66.24	65.58
20	12.15	102.73	83.98	79.29	76.48	74.61	70.86	69.56	68.87
21	13.89	117.44	96.01	90.65	87.44	85.30	81.01	79.52	78.73
22	14.18	119.89	98.01	92.54	89.26	87.08	82.07	81.18	80.37
23	16.20	136.97	111.97	105.72	101.98	99.48	94.48	92.75	91.82

Note 1: Determine grams required from the table or formula below it. Locate nearest line (or interpolate between two lines) and read $ in appropriate ratio column.

Note 2: Cost per gram calculated at Platinum $167/Troy oz. = $5.369/gram and Rhodium $455/Troy oz. = $14.628/gram.

Note 3: When Rhenium, Ruthenium of Nickel are also included in the compound, multiply the value from the table by the combined percentages of Platinum and Rhodium; add to this the remaining percentage times $.67 times total grams required.

4. DETERMINATION OF SUBSTRATE SHELL DIMENSIONS

4.1 Imposed Space Limits to Shell

Diameter Shell - 6.0"
Length Shell - 240"

4.2 Implied space limits to substrate

Diameter - 6.0 - 0.5 (metal mesh) = 5.5"
Length - 24.0 - 1.1 (endcap) = 22.9"

4.3 Two selected shell diameters to accommodate the range of substrate volumes: (refer to graph 4.3)

Vol (in)	Dia (in.)	Length (in.)
0-150	4.0	0-15.1
151-400	5.4	9.7-24.0

4.4 Length of shell required at given substrate volume.

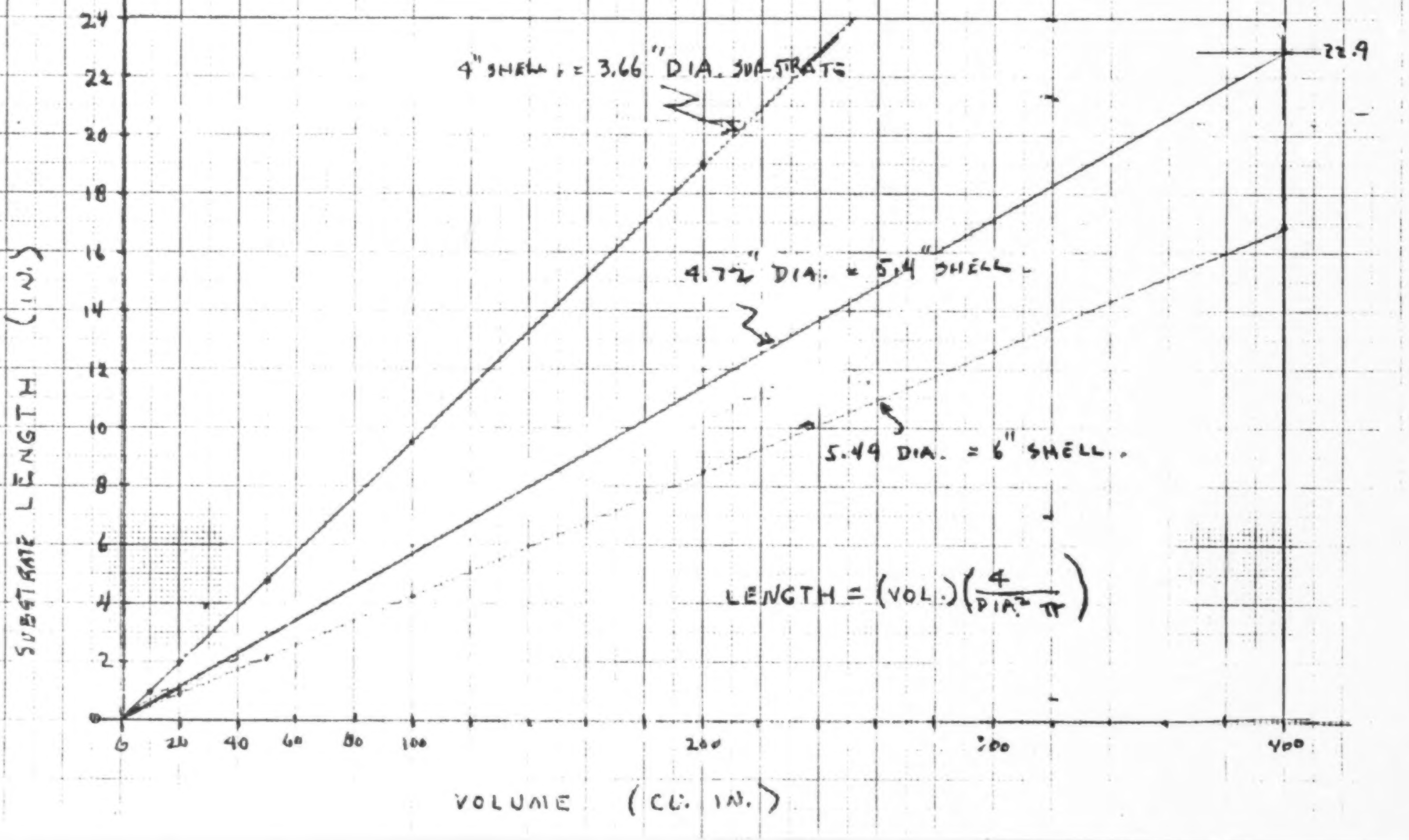
Substrate Volume (in)	Dia. Shell (incl. mesh)	Length Shell (incl. ca2)
1	4.0	.10+1.1= 1.1
10	4.0	.95+1.1= 2.1
20	4.0	1.90+1.1= 3.0
50	4.0	4.75+1.1= 5.9
100	4.0	9.50+1.1=10.6
150	4.0	14.26+1.1=15.4
151	5.4	8.63+1.1= 9.7
200	5.4	11.43+1.1=12.5
250	5.4	14.29+1.1=15.4
300	5.4	17.15+1.1=18.3
350	5.4	20.00+1.1=21.1
400	5.4	22.86+1.1=23.9

Ref: Pg 92

GRAPH 4.3

LENGTH OF SUBSTRATE REQUIRED TO ATTAIN VOLUME
AT THREE SPECIFIC DIAMETERS

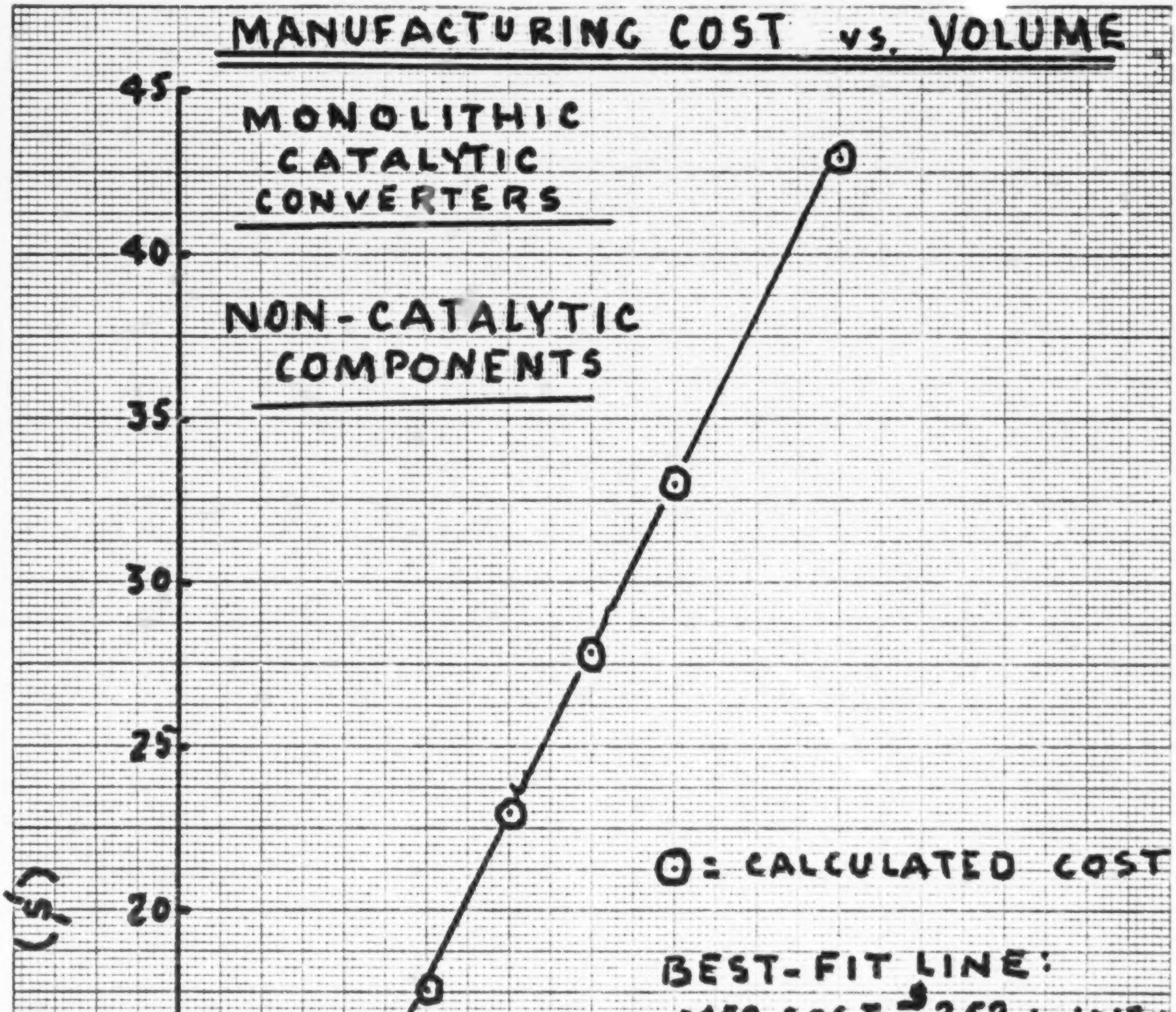
LIMITS: LENGTH 24" MAX. OVERALL SHELL ; LESS 1.1 = 22.9" MAX LENGTH OF SUBSTRATE
VOLUME 400 IN^3 MAX.



$$\text{LENGTH} = (\text{VOL.})\left(\frac{4}{\text{DIA}^2\,\pi}\right)$$

5. DETERMINATION OF RING DIAMETER

Volume Substrate In.	Dia. Ring In.
0-150	4.0
151-400	5.4


MANUFACTURING COST vs. VOLUME
MONOLITHIC CATALYTIC CONVERTERS
NON-CATALYTIC COMPONENTS
⊙ = CALCULATED COST
BEST-FIT LINE:
MFG. COST = $2.52 + .1013×V
MFG. COST ($)
VOLUME (IN.³)
0
5
10
15
20
25
30
35
40
45
0
100
200
300
400

MFG. COST CALCULATIONS - NONCATALYTIC COMPONENTS

		Vol. - 63 (Base) Dia. - 4 Lgth. - 7.2					Vol. - 10 Dia. - 4 Lgth. - 2.1				
Part	Mat'l	Weight	Mat'l Cost	Labor	OH	Mfg. Cost	Weight	Mat'l Cost	Labor	OH	Mfg. Cost
Cvtr. Assy.			-	.2500	.1000	.3500		-	.1884	.0754	.2638
Shell	409 SS	2.00	.80	.0625	.0250	.8875	.76	.30	.0393	.0157	.3550
Rings (No.)	409 SS	1.00	.40	.0312	.0125	.4437	.50	.20	.0156	.0062	.2218
In. Cone	409 SS	1.00	.40	.0312	.0125	.4437	1.00	.40	.0312	.0125	.4437
Out. Cone	409 SS	1.00	.40	.0312	.0125	.4437	1.00	.40	.0312	.0125	.4437
In. Pipe	409 SS	1.00	.40	.0312	.0125	.4437	1.00	.40	.0312	.0125	.4437
Flanges	409 SS	.25	.10	.0156	.0062	.1218	.25	.10	.0156	.0062	.1218
Mesh	409 SS	.15	.06	.0156	.0062	.0818	.04	.02	.0088	.0035	.0323
Hdwr.	Steel	.10	.02	.0156	.0062	.0418	.10	.02	.0156	.0062	.0418
Substrt.	Ceramic	1.30	4.68	.1250	.0500	4.8550	.21	.76	.0618	.0247	.8465
Wash Coat	Al_2O_3	-	.60	.0625	.0250	.6875		.10	.0309	.0124	.1433
	TOTALS		7.86	.6716	.2686	8.8002		2.70	.4696	.1878	3.3574

		Vol. - 100 Dia. - 4 Lgth. - 10.6					Vol. - 150 Dia. - 4 Lgth. - 15.4				
Cvtr. Assy.		9.46	-	.2857	.1143	.4000	12.27	-	.3445	.1378	.4823
Shell	409 SS	2.83	1.13	.0781	.0312	1.2393	4.00	1.60	.1000	.0400	1.7400
Rings (No.)	409 SS	1.00	.40	.0312	.0125	.4437	1.50	.60	.0468	.0187	.6655
In. Cone	409 SS	1.00	.40	.0312	.0125	.4437	1.00	.40	.0312	.0215	.4437
Out. Cone	409 SS	1.00	.40	.0312	.0125	.4437	1.00	.40	.0312	.0125	.4437
In. Pipe	409 SS	1.00	.40	.0312	.0125	.4437	1.00	.40	.0312	.0125	.4437
Flanges	409 SS	.25	.10	.0156	.0062	.1218	.25	.10	.0156	.0062	.1218
Mesh	409 SS	.22	.09	.0200	.0080	.1180	.32	.13	.0262	.0105	.1667
Hdwr.	Steel	.10	.02	.0156	.0062	.0418	.10	.02	.0156	.0062	.0418
Substrt.	Ceramic	2.06	7.42	.1684	.0674	7.6558	3.10	11.16	.2284	.0914	14.4798
Wash Coat	Al_2O_3		.95	.0842	.0337	1.0679		1.43	.1142	.0457	1.5899
	TOTALS		11.31	.7924	.3170	12.9194		16.24	.9849	.3940	17.6189

MFG. COST CALCULATIONS - NONCATALYTIC COMPONENTS

		Vol. - 200 Dia. - 5.4 Lgth. - 12.5					Vol. - 250 Dia. - 5.4 Lgth. - 15.4				
Part	Mat'l	Weight	Mat'l Cost	Labor	OH	Mfg. Cost	Weight	Mat'l Cost	Labor	OH	Mfg. Cost
Cvtr. Assy.		15.60	-	.4125	.1650	.5775	17.67	-	.4580	.1832	.6412
Shell	409 SS	4.56	1.82	.1105	.0442	1.9747	5.52	2.21	.1285	.0514	2.3899
Rings (No.)	409 SS	2.03	.81	.0567	.0227	.8894	2.03	.81	.0567	.0227	.8894
In. Cone	409 SS	1.35	.54	.0378	.0151	.5929	1.35	.54	.0378	.0151	.5929
Out. Cone	409 SS	1.35	.54	.0378	.0151	.5929	1.35	.54	.0378	.0151	.5929
In. Pipe	409 SS	1.35	.54	.0378	.0151	.5929	1.35	.54	.0378	.0151	.5929
Flanges	409 SS	.34	.14	.0190	.0076	.1666	.34	.14	.0190	.0076	.1666
Mesh	409 SS	.35	.14	.0281	.0112	.1793	.43	.17	.0331	.0132	.2163
Hdwr.	Steel	.14	.03	.0193	.0078	.0571	.14	.03	.0193	.0078	.0571
Substrt.	Ceramic	4.13	14.87	.2880	.1152	15.2732	5.16	18.38	.3476	.1391	19.0667
Wash Coat	Al_2O_3		1.90	.1440	.0576	2.1016	-	2.38	.1738	.0695	2.6233
	TOTALS		21.33	1.1915	.4766	22.9981		25.94	1.3494	.5398	27.8292

		Vol. - 300 Dia. - 5.4 Lgth. - 18.3					Vol. - 400 Dia. - 5.4 Lgth. - 23.9				
Cvtr. Assy.		20.40	-	.5153	.2061	.7214	25.14	-	.6175	.2470	.8645
Shell	409 SS	6.47	2.59	.1463	.0585	2.7948	8.31	3.32	.1808	.0723	3.5731
Rings (No.)	409 SS	2.70	1.08	.0756	.0302	1.1858	3.38	1.35	.0945	.0378	1.4823
In. Cone	409 SS	1.35	.54	.0378	.0151	.5929	1.35	.54	.0378	.0151	.5929
Out. Cone	409 SS	1.35	.54	.0378	.0151	.5929	1.35	.54	.0378	.0151	.5929
In. Pipe	409 SS	1.35	.54	.0378	.0151	.5929	1.35	.54	.0378	.0151	.5929
Flanges	409 SS	.34	.14	.0190	.0076	.1666	.34	.14	.0190	.0076	.1666
Mesh	409 SS	.51	.20	.0381	.0152	.2533	.67	.27	.0480	.0192	.3372
Hdwr.	Steel	.14	.03	.0193	.0078	.0571	.14	.03	.0193	.0078	.0571
Substrt.	Ceramic	6.19		.4072	.1629	22.8501	8.25		.5261	.2104	30.4365
Wash Coat	Al_2O_3	-	2.86	.2036	.0814	3.1450	-	3.81	.2630	.1052	4.1782
	TOTALS		30.80	1.5378	.6150	32.9528		40.24	1.8816	.7526	42.8742

Noble Metal Prices

Metal	Price per Troy Ounce* Wholesale	Price per Troy Ounce* Retail
Platinum	$162	$172
Iridium	300	310
Rhodium	400	410
Paladium	60	65
Ruthenium	60	65

---

*Troy Ounce = 31.1035 grams

Source: Matthey-Bishop, Inc.

CORNING GLASS WORKS
CORNING
1800 K STREET, N.W.
WASHINGTON, D. C. 20006
202 296-8040

April 6, 1977

John DeKany
Director
Emission Control Technology Division
U.S. Environmental Protection Agency
2565 Plymouth Road
Ann Arbor, Michigan 48105

Dear John:

Here is some data that will help you estimate the cost of emission control systems to the manufacturers of automobiles.

All of our substrates, regardless of passage size or composition, can be estimated as follows:

Selling price per pound = $3.60
Selling price per cubic foot = $138
Product density - 200 passages per square inch = 28.2 - 38.5 pounds per cubic foot
For 236 passages per square inch = 31.9 - 39.4 pounds per cubic foot
For 300 passages per square inch = 36.0 - 48.0 pounds per cubic foot.

I am delighted that we have been able to come up with some guidance for you and I hope you get some help from the rest of our group. Let me know if you think they need a reminder.

Sincerely,

John

John R. Blizard

JRB/kcd

cc: Karl Hellman

EVOLUTION OF DISTRIBUTION AND ECONOMICS

AUTOMOTIVE AFTERMARKET

ERAS: 1912-1928

1925-1940

1940-1950

1950-1960

1960-1977

TO INCLUDE:

THE METHODOLOGY

THE ECONOMICS

THE CONFLICTS

THE OUTGROWTHS

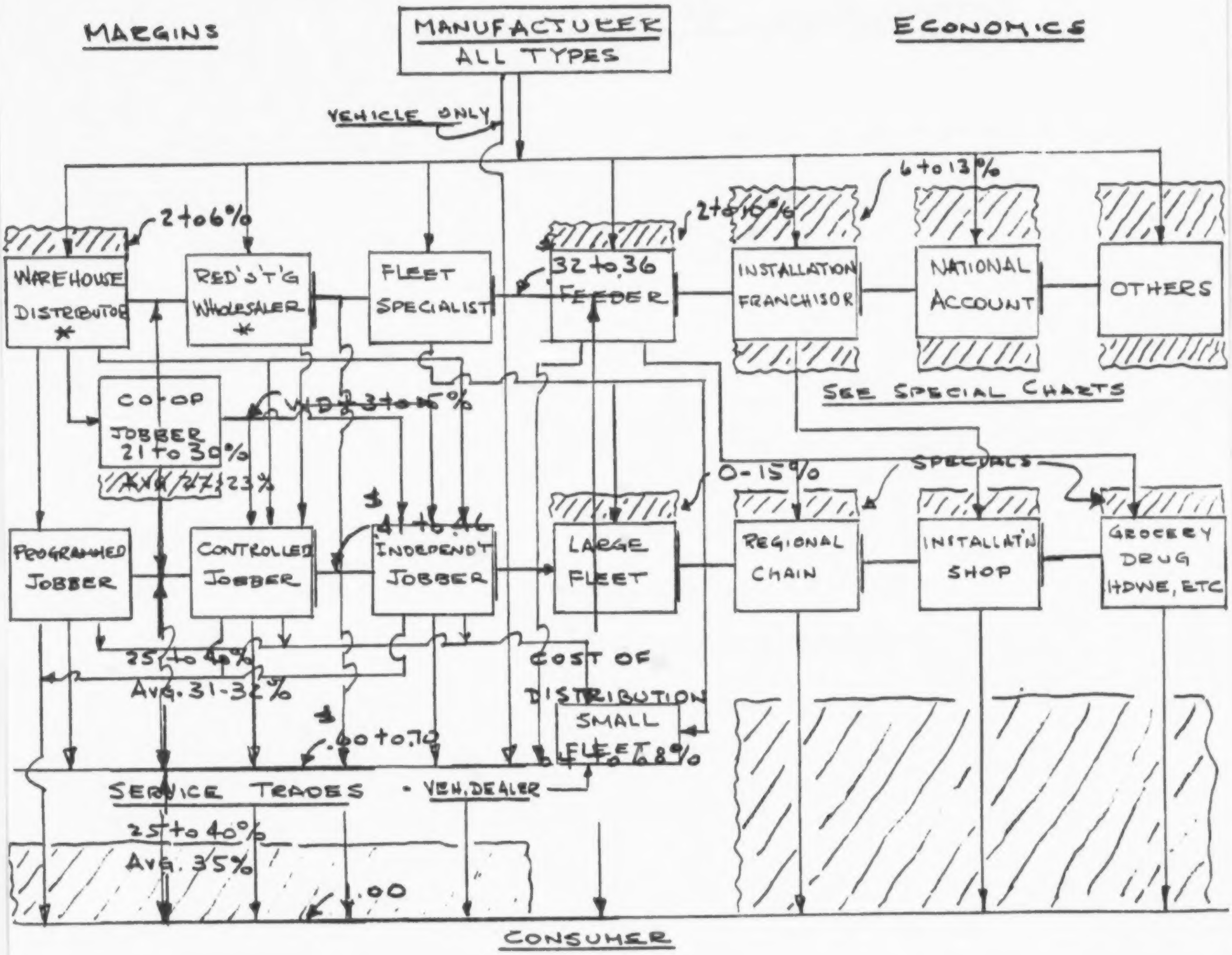
AN ADDRESS BY: J.M. YANTIS, CHAIRMAN
MID-AMERICA INDUSTRIES, INC.

BEFORE: DISTRIBUTORS INSTITUTE
DRAKE HOTEL
CHICAGO
MARCH 11, 1977

SLIDE 1

ERA 1960 - 1977

THE MATURING YEARS

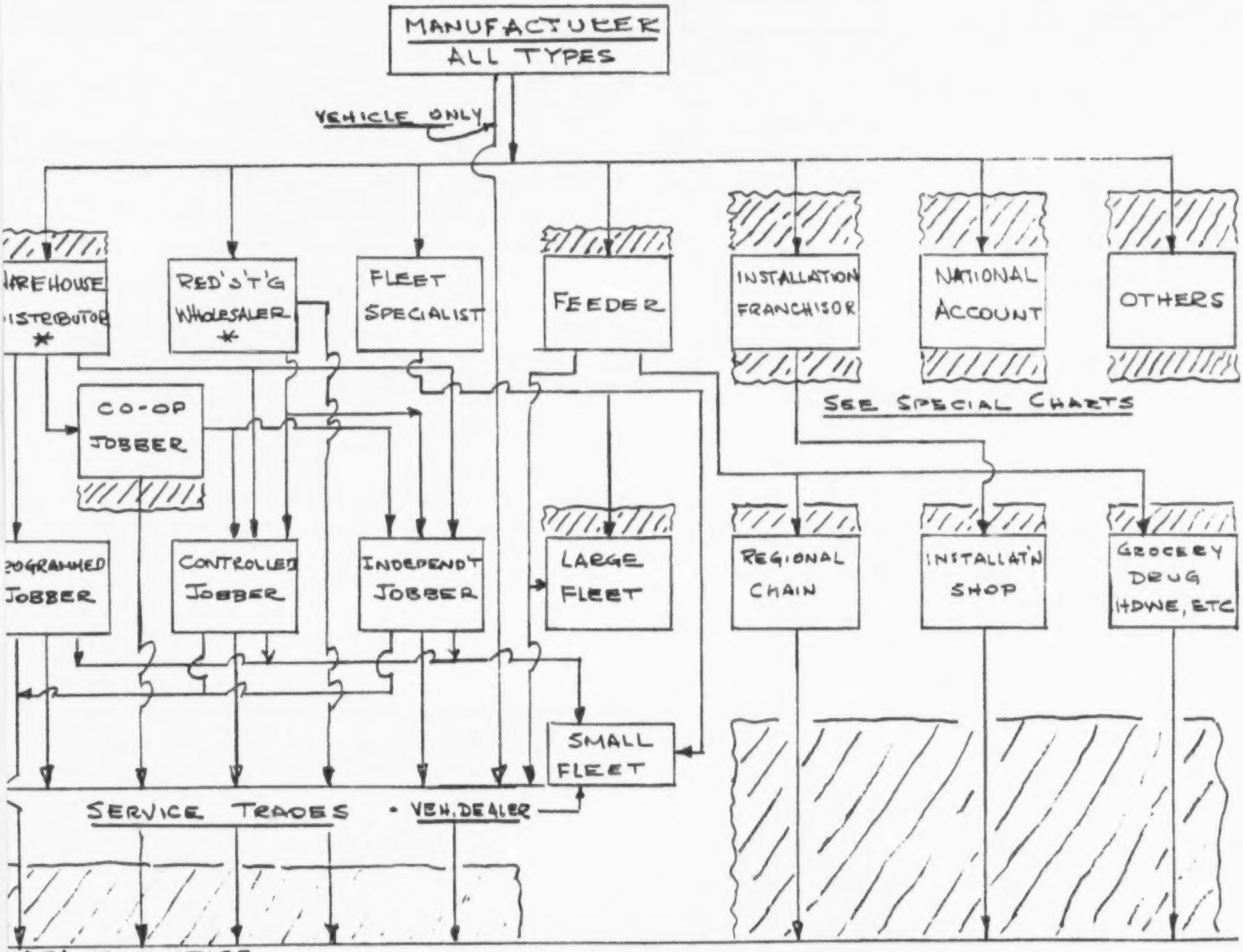

MARGINS
MANUFACTURER ALL TYPES
ECONOMICS
VEHICLE ONLY
2 to 6%
WAREHOUSE DISTRIBUTOR *
RED'S'T'G WHOLESALER *
FLEET SPECIALIST
$ 32 to .36
FEEDER
2 to 6%
6 to 13%
INSTALLATION FRANCHISOR
NATIONAL ACCOUNT
OTHERS
SEE SPECIAL CHARTS
CO-OP JOBBER 21 to 30%
AVG 27 23%
WD 3 to 5%
$ .41 to .46
PROGRAMMED JOBBER
CONTROLLED JOBBER
INDEPEND'T JOBBER
LARGE FLEET
0-15%
SPECIALS
REGIONAL CHAIN
INSTALLAT'N SHOP
GROCERY DRUG HDWE, ETC
25 to 40%
Avg. 31-32%
COST OF DISTRIBUTION
SMALL FLEET
.64 to .68%
$ .60 to .70
SERVICE TRADES
VEH. DEALER
25 to 40%
Avg. 35%
$ 1.00
CONSUMER

* ALSO ATTEMPT TO SELL LARGE FLEETS AND INSTALLATION SHOPS.

SLIDE 6
PART 2
SLIDE 6
PART 1

ERA 1960 - 1977

THE MATURING YEARS


MANUFACTURER
ALL TYPES
VEHICLE ONLY
AREHOUSE
ISTRIBUTOR
*
RED'S'T'G
WHOLESALER
*
FLEET
SPECIALIST
FEEDER
INSTALLATION
FRANCHISOR
NATIONAL
ACCOUNT
OTHERS
SEE SPECIAL CHARTS
CO-OP
JOBBER
ROGRAMMED
JOBBER
CONTROLLED
JOBBER
INDEPEND'T
JOBBER
LARGE
FLEET
REGIONAL
CHAIN
INSTALLAT'N
SHOP
GROCERY
DRUG
HDWE, ETC
SMALL
FLEET
SERVICE TRADES
• VEH. DEALER

HARACTERISTICS

CONSUMER

. ADDED CHANNELS OF DISTRIBUTION.

2. NEW FLEXIBILITIES IN PRICING.

3. NEW PRICING PHENOMENON BASED ON 'COST-JUSTIFICATION' - 'MEETING COMPETITION' - 'PRIVATE BRANDING' - 'BIDDING'.

4. ELIMINATION OF REPORTING FOR FUNCTIONAL COMMISSION.

5. MANUFACTURERS LOSS OF CONTROL OF DISTRIBUTION.

6. OPENING OF WIDE MARGIN BETWEEN MANUFACTURERS RECOMMENDED CONSUMER PRICE & MANY RETAILERS COST.

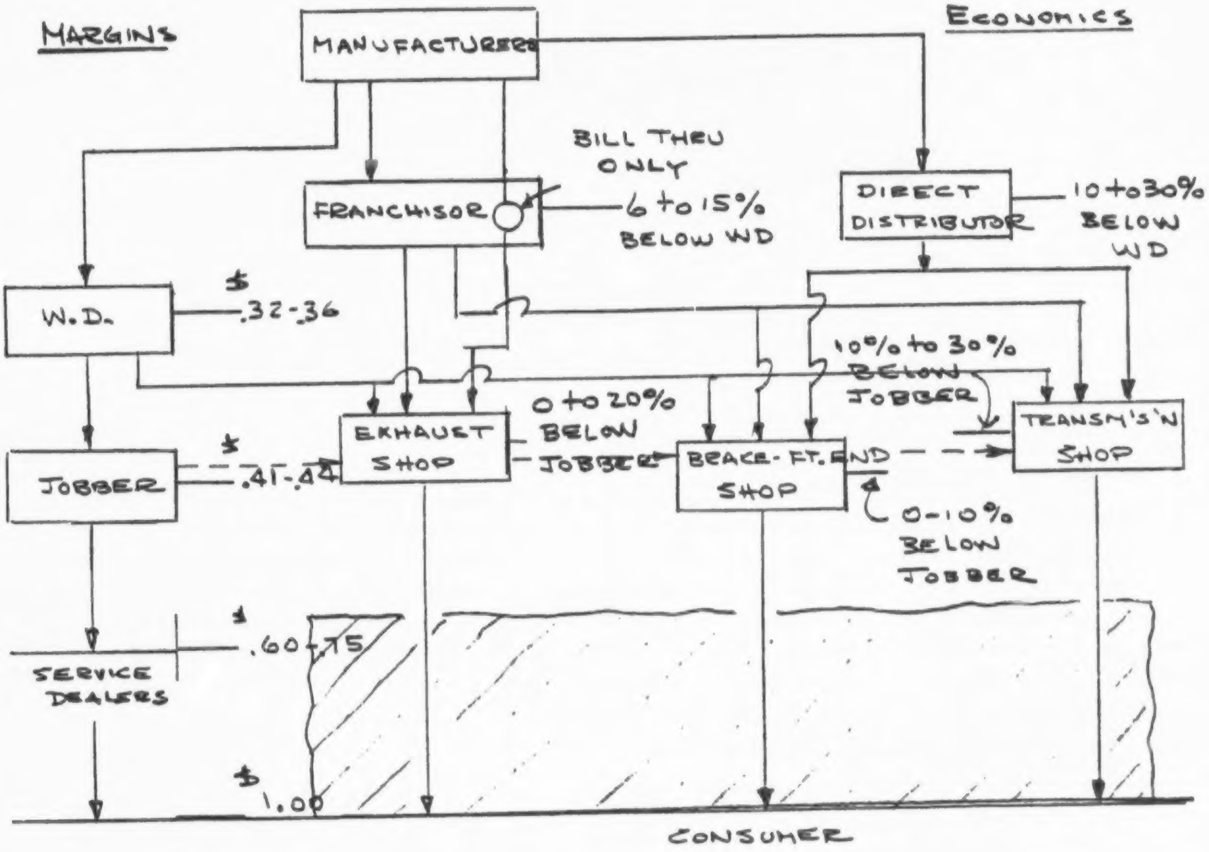
SLIDE 6
PART 3

7. ENTER 'SELF-INSTALLER' - ADVERTISING - STORE MODERNIZATION - JOBBERS RENDERING RETAIL SERVICE, ETC.

SLIDE 6
PART 1

* ALSO ATTEMPTS TO SELL LARGE FLEETS AND INSTALLATION SHOPS.

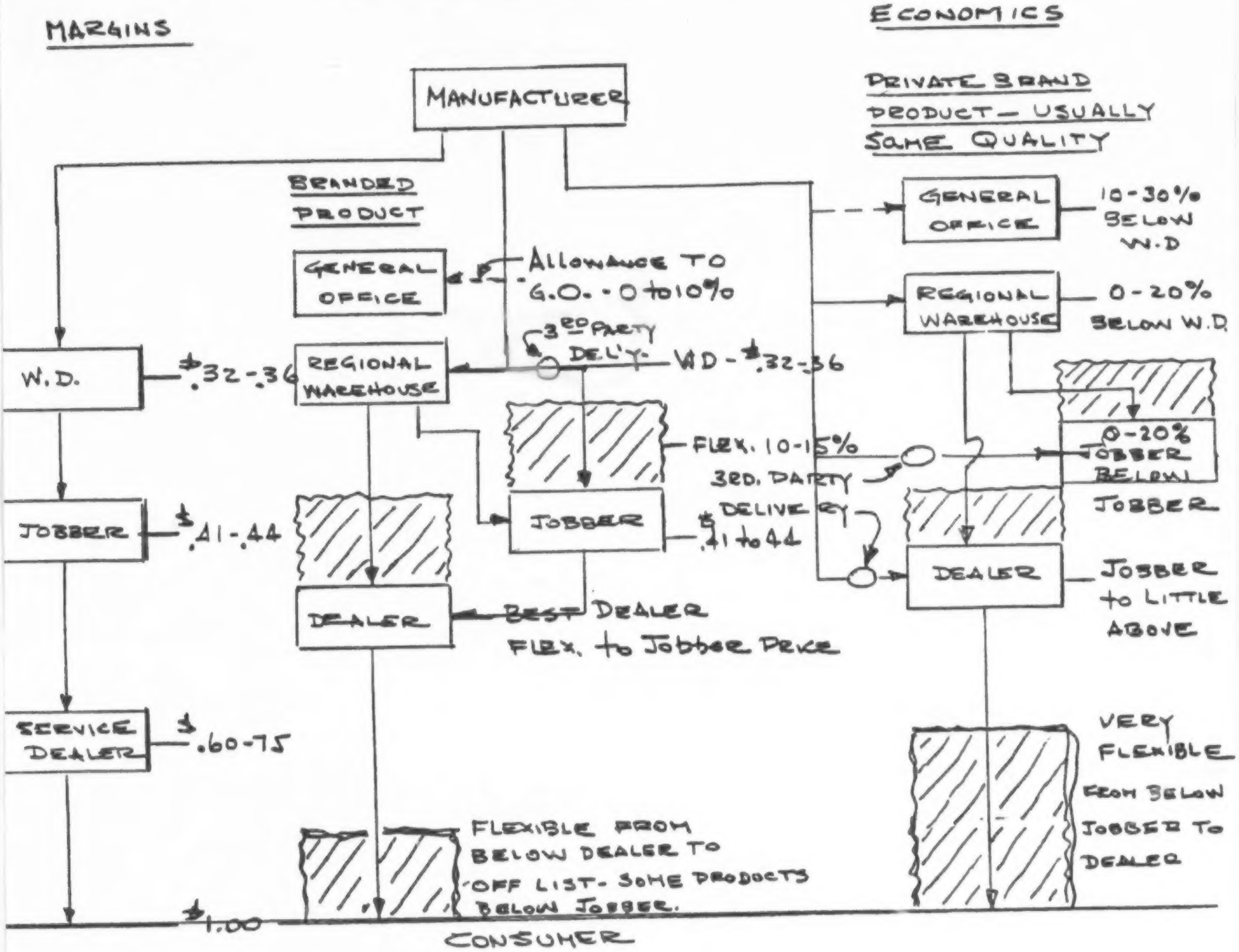
THE INSTALLATION SHOPS


MARGINS
MANUFACTURERS
ECONOMICS
BILL THRU ONLY
FRANCHISOR
6 to 15% BELOW WD
DIRECT DISTRIBUTOR
10 to 30% BELOW WD
W.D.
$ .32-.36
10% to 30% BELOW JOBBER
0 to 20% BELOW JOBBER
EXHAUST SHOP
BRAKE-FT. END SHOP
TRANSM'S'N SHOP
JOBBER
$ .41-.44
0-10% BELOW JOBBER
$ .60-.75
SERVICE DEALERS
$ 1.00
CONSUMER

SLIDE 7
PART 2

SLIDE 7
PART 1

THE NATIONAL ACCOUNTS


MARGINS
ECONOMICS
MANUFACTURER
BRANDED PRODUCT
PRIVATE BRAND PRODUCT – USUALLY SAME QUALITY
GENERAL OFFICE
ALLOWANCE TO G.O. - 0 to 10%
W.D.
$.32-.36
REGIONAL WAREHOUSE
3RD PARTY DEL'Y.
WD - $.32-.36
FLEX. 10-15%
3RD. PARTY DELIVERY
JOBBER
$.41-.44
JOBBER
$.41 to 44
DEALER
~~BEST~~ DEALER FLEX. to Jobber Price
SERVICE DEALER
$.60-.75
FLEXIBLE FROM BELOW DEALER TO OFF LIST - SOME PRODUCTS BELOW JOBBER.
$1.00
CONSUMER
GENERAL OFFICE
10-30% BELOW W.D
REGIONAL WAREHOUSE
0-20% BELOW W.D.
0-20% JOBBER BELOW JOBBER
DEALER
JOBBER to LITTLE ABOVE
VERY FLEXIBLE FROM BELOW JOBBER TO DEALER

SLIDE 8
PART 2

SLIDE 8
PART 1